SCIENTIFIC AGRICULTURE

Vol. XI. MAY, 1931 No. 9

# THE EXPERIMENTAL MODIFICATION OF HEREDITY IN CROP PLANTS *†

## I. INDUCED CHROMOSOMAL IRREGULARITIES ‡

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Heritable differences between related individuals, in the higher plants and animals, are due in the main to separable units within the chromosomes. This generalization has been securely established by modern experimental genetics. The evidence applies strictly only to differences between strains closely enough related to be cross-fertilized, since the differences between larger groups are beyond the reach of present genetic technic; but its much broader application may reasonably be inferred. The units of heredity carried by the chromosomes are called the genes. One exceptional category of heritable differences is known, that of certain relatively infrequent variations which follow the distribution of cytoplasmic constituents rather than that of the chromosomes.

The germinal variability which provides the basis for plant and animal breeding and for evolutionary change is largely the result of recombinations of a nearly constant stock of genes. An individual normally possesses two sets of genes, one set from each parent. Of each gene there may exist several alternative forms (allelomorphs) of varying effect, any two of which may be present in the normal individual. Even in species with a rather small number of different genes, therefore, the possible variations by recombination are almost unlimited. These are produced in great variety by cross-fertilization. There are also variations due to the absence or reduplication of some of the genes or of whole sets of genes, or to the rearrangement of genes in the chromosomes. These occur rarely as the result of some irregularity of chromosome behavior.

In addition to these sources of variability, which produce new combinations of pre-existing genes, there are occasional changes in the genes themselves. This is presumably the basic evolutionary process producing the qualitative variations which are recombined and reorganized by hybridization and chromosomal irregularities. A change in the individual gene is called a mutation. It should be noted, however that changes limited to the individual gene are probably of various types, and that some of these may be closely

* Lectures before the tenth annual convention of the Canadian Society of Technical Agriculturists, Wolfville, Nova Scotia, June 24 and 25, 1930.

† A general account of the results of these experiments to May, 1929, has been published in the Journal of Heredity (8). This should be consulted in connection with the present summary, since unnecessary repetition of material included in the earlier report has been avoided in preparing the lectures for publication.

‡ The remainder of this communication (II. Induced Mutation) will be published in the June number of this journal.

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** The experiments reported were supported in part by a grant of funds and equipment by the National Research Council, Committee on Effects of Radiation on Living Organisms.

analogous to the grosser rearrangements which we distinguish as chromosomal irregularities. The determination of the physical nature of mutation, or of such types of mutation as may be experimentally affected, is one of the principal objectives of genetic experiments with radiation. Until we have more accurate knowledge of the physical nature of the phenomena, it is convenient to retain the familiar classification of germinal changes as chromosomal and genic. In this paper the induced germinal changes which may be traced to chromosomal irregularities are discussed. Induced changes apparently limited to the individual gene will be discussed in the second paper.

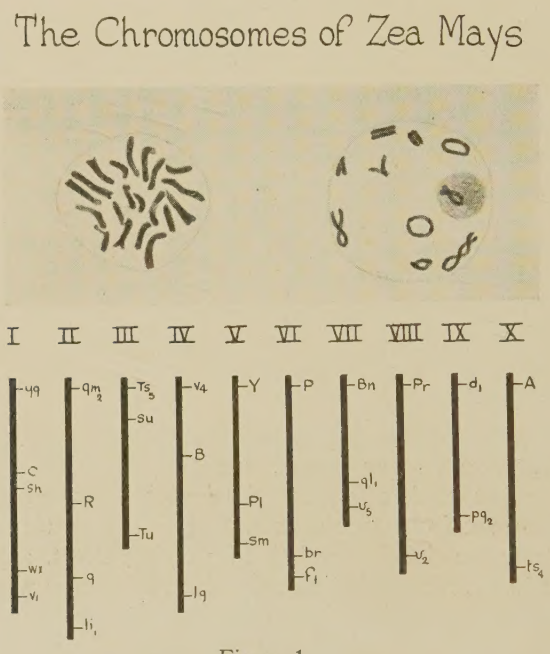


Figure 1.

Figure 1. Chromosomes and Linkage Groups in Maize. Upper left, a microsporocyte at diakinesis, showing 10 bivalents; upper right, a root-tip cell, showing 20 somatic chromosomes. After Randolph (*5*). Lower, the 10 linkage groups, with the principal loci indicated. The linkage relations have been determined largely by Prof. R. A. Emerson and his students.

## Effects of Irradiation of Pollen

The occurrence of chromosomal irregularities induced by X-rays is most clearly shown in the results of pollen treatment. As previously reported (*7*), untreated plants pollinated by irradiated pollen produced a considerable proportion of seeds with defective endosperms or embryos. Their progeny included defective plants with cytologically detectable chromosomal deficiencies. This indicated that some of the male germ cells treated had lost a portion of the normal chromosome complement.

Genetic evidence of the chromosome regions involved in these losses may be secured by "marking" the chromosomes of the male parent with dominant genes of which the corresponding recessives are present in the female parent. The progeny would normally show the dominant characters, but if any of the dominant genes were lost as a result of the pollen treatment, the cor-

responding recessive characters would appear. Seven of the maize chromosomes may be marked by genes for endosperm character: one by three genes, *C, Sh,* and *Wx,* another by two genes, *Y,* and *Bh,* and the other five by one gene each, *A, R, Pr, In,* and *Su.*

*Loss of dominant endosperm characters.*—The use of endosperm "markers" in determining the effects of pollen treatment is illustrated by the ear pictured in figure 2. This ear was produced by an untreated plant of constitution *a pr su,* pollinated by *A Pr Su* pollen which had been irradiated (dose 1200 *r*) just before pollination. The *A a Pr pr Su su* seeds normally produced by this cross are purple starchy; the loss of *A* is shown by the absence of aleurone color, the loss of Pr by the development of red aleurone instead of purple, and the loss of *Su* by the development of wrinkled (sugary) endosperm instead of smooth. Of the 220 seeds borne by this ear 32 were colorless, 14 red, and 17 sugary. About 30 per cent of the seeds were distinctly defective in endosperm or embryo development.

Since each chromosome is marked by only one gene in this cross, the disappearance of a dominant gene (as indicated by the appearance of the corresponding recessive character) may result from either deficiency or recessive mutation. When two or more genes are used to mark a single chromosome a deficiency of sufficient extent to include more than one locus may be distinguished from a recessive mutation by the simultaneous disappearance of two or more dominants.

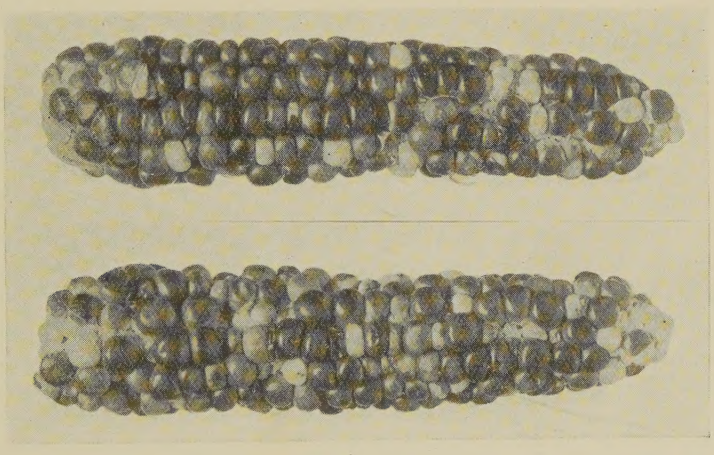

Figure 2.

Figure 2. An ear of an untreated *a pr su* plant pollinated by irradiated *A Pr Su* pollen.

Evidence from trials with the three linked genes *C, Sh,* and *Wx* indicates that this disappearance of dominant genes following irradiation of pollen is usually the result of deficiency rather than mutation. When a *c sh wx* ear is pollinated by treated *C Sh Wx* pollen, many of the grains produced are colorless, as in the trial with *A,* but the majority of these are also shrunken and waxy. In other words, when *C* disappears, *Sh* and *Wx* usually disappear also. This is assumed to be the result of deficiency, that is, the absence or inactivity

of all or part of the string of genes borne by a single chromosome. In many of the defective plants, as stated above, there is cytological evidence of the absence of certain chromosomes or chromosome fragments, but in the deficiencies found in endosperm tissue the only evidence for the "loss" of genes is the phenotypic effect. About 25 or 30 per cent of the colorless grains are shrunken but not waxy, indicating that the string of genes lost included *C* and *Sh* but did not extend to *Wx*. There are also a few colorless grains which are not shrunken or waxy. This group may include grains resulting from recessive mutation of *C*, but some of these grains at least are doubtless the result of deficiencies which included *C* but did not extend to *Sh*. Of the total number of colorless grains observed, therefore, the number due to recessive mutation of *C* cannot make up more than a small proportion. It is possible that all of the losses—*C*, *C-Sh*, and *C-Sh-Wx*—may be due to losses of part of the chromosome (sectional deficiency).

Genes in six chromosomes *A*, *C*, *R*, *Pr*, *Su*, and *Y* have been extensively used as markers in experiments of this sort. The frequency of loss for a given dose varies somewhat for the genes tested, *A* having the highest frequency and *Y* the lowest.

The frequency of deficiency induced by irradiation of pollen is directly proportional to dosage. Figure 3 shows this relation for a series of pollen treatments of 400, 800, and 1200 *r*, in a cross in which five chromosomes were marked. The populations in which the frequencies were determined were about 1000 for each dose. For each gene the frequency of loss was roughly proportional to the dose. When the frequencies of loss for all five genes are totaled, to minimize sampling fluctuations, the approach to strict proportionality is fairly close. The frequency of loss per 1000 *r* varies from about 6 per cent for *Sh* to about 2 per cent for *Y*.

*Recovery*.—An interesting and quite unexpected feature of the deficiencies is the occasional appearance of apparent reversion to the non-deficient condition. Among the colorless seeds which apparently have lost a dominant gene for aleurone color, a few may have one or more small areas of colored tissue, as if the gene lost had been recovered. This occurs for each of the aleurone color genes, *A*, *C* and *R*, and a corresponding change from red to purple is found in endosperms which have lost *Pr*. The total area showing the dominant character is usually only a very small fraction of the entire endosperm. It is most frequently a single spot, but often there are two to several separate spots, usually distinctly clustered. Two of the seeds shown in figure 2 are typical examples of deficiency and recovery of *A*. They are colorless seeds except for two small spots of colored tissue. One of these, enlarged to show the colored spots more distinctly, is shown in figure 4.

These cases, considered alone, would be interpreted as instances of recessive mutation induced by irradiation of the pollen, followed late in endosperm development by reverse dominant mutation. But corresponding cases in seeds in which the linked genes *C* and *Wx* are used together as markers, indicate that the phenomenon is chromosomal rather than genic. Endosperms which are colorless and waxy, due to the loss of both *C* and *Wx*, show similar spots of colored tissue. The colored areas are in all cases starchy (*Wx*);

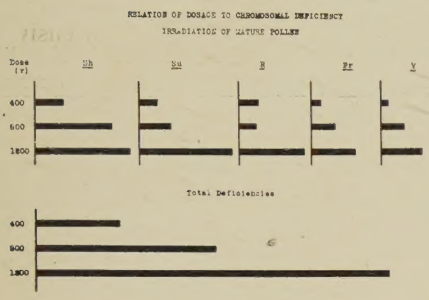


Figure 3.

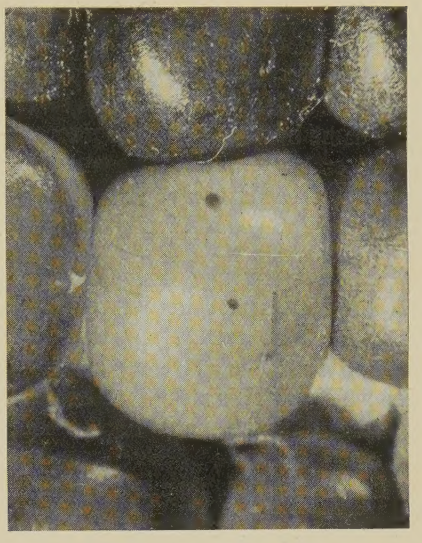

Figure 4.

Figure 3. Effect of X-ray Dosage on the Frequency of Deficiency.

Figure 4. Recovery following genetic deficiency in the endosperm. This is an enlargement of a grain shown in figure 2.

indicating that the reversion has restored both *C* and *Wx*. (The *Sh* locus, when marked, is also found to be involved in the loss, but since its effect cannot be detected in the small areas showing the dominant characters, it cannot be followed in recovery).

The mechanism of recovery is unknown. It is conceivable that deficiency may be in some cases a reversible inactivation of a chain of genes, without effect on their regular reproduction in successive cell generations. The inactivated genes then would be present in all cells of the deficient sector, and might revert in any cell. You may if you prefer consider this assumed change in the genes a "chain mutation," or a simultaneous mutation of a chain of genes, first to a recessive condition and later in the reverse direction. But simultaneous changes in the genes as individuals are hardly conceivable without a unifying physical mechanism, when the chain affected is as long as in this case. A more plausible hypothesis is that the affected region has, through some chromosomal injury or rearrangement, lost the power of reproducing itself in the two daughter cells resulting from each mitosis. Unless the power of reproduction is regained these genes would be present in only one cell of the mature endosperm, and their effect would be inappreciable. Recovery could occur only in a cell which contained the affected genes. On this hypothesis, the effects of deficiency would be ascribed to absence of the genes concerned, without the necessity for any assumption of a change in gene activity. The evidence now at hand does not provide an adequate basis for more definite speculation regarding the physical nature of the original change in the treated nucleus. Whatever the mechanism, it is clear that the variation induced in treated pollen, which usually leads to results typical of genetic deficiency, is a reversible variation.

*Defective seeds.*—Defective seeds are of two types, miniature and germless. Miniature seeds are reduced to a fraction of the normal volume, chiefly by reduction in the size of the endosperm. They may have fully normal embryos. Germless seeds are similar to the types previously described under that name by several investigators in maize genetics. They have only vestiges of an embryo, but may have fully developed endosperms. Apparently the miniature seeds are the result of a defect in endosperm development, and the germless seeds of a defect in embryo development.

The frequency of occurrence of defective seeds is not proportional to intensity, the rate per *r*-unit for both types rising sharply with heavy dosage. The reason for this is not yet determined. There is reason to suspect that miniature seeds may be the result of only the more extensive deficiencies. It is clear that not all deficiencies cause defective endosperm development, since many of the endosperms showing recessive characters are normally developed. But some connection between deficiency and defective endosperm development is indicated by the fact that the proportion of recessives among the defective endosperms is distinctly higher than among the normally developed endosperms. The probability that the deficient regions may include genes essential to normal endosperm development is twice as great in nuclei with two deficiencies as in those with only one. To the extent that the occurrence of defective endosperms is dependent on such coincidences, its increase with dosage would be exponential rather than direct. This may be the explanation of the sharp rise in frequency of miniature seeds with the heavier treatment.

*Loss of dominant plant characters.*—The loss of portions of the chromosome complement of the pollen nucleus which fertilizes the egg has been shown in earlier experiments with pollen irradiation, Among the plants grown from seeds produced by the use of treated pollen, many were extremely defective in growth. These were of several distinct types, but all were characterized by reduced size, late flowering and a high proportion of aborted pollen. Cytological examination by Randolph (*6*) showed in many of these plants the absence of one or more chromosomes or cytologically detectable chromosome fragments. Dr. Randolph's report has not yet been published, and he has kindly permitted me to show two figures representing typical chromosomal effects of radiation (figures 5 and 8). Figure 5 shows the anaphase of the first meiotic division in a defective plant which proved to be deficient for an entire chromosome.

The genetic makeup of these deficiencies may be determined by the method used in the study of endosperm deficiency, if genes affecting plant characters are used as markers instead of genes affecting endosperm characters. A few genes may be used as markers in both endosperm and plant. The most useful of these is *A*, the basic anthocyan factor. In the presence of the proper accessory genes, the loss of *A* may be detected in the endosperm, embryo, seedling, or mature plant.

We may now return to our specimen ear (figure 2). When the seeds of such an ear are planted, the resulting crop includes a considerable number of defective plants. A few of the defective plants show by the absence of

anthocyan pigment the loss of the gene *A*. There are also a few plants which have lost *A* but which are not sufficiently defective to have been identified as deficient plants in the absence of a marker. Plants of this class, like the defective plants, produce at least 50 per cent aborted pollen. These plants probably represent the less extensive deficiencies which include the *A* locus. Their occurrence was expected from the fact that the distinctly defective plants previously found were in general characterized by deficiencies so extensive as to be cytologically recognizable. Since many of the deficiencies are sectional and these are variable in extent, it was reasonable to expect that less extensive deficiencies also occurred. These would not be recognizable by their general effect on vigor, but would be detected if the deficient region were marked by a dominant gene. The frequency of deficiency induced by the treatment, therefore, is considerably greater than the frequency of distinctly defective plants.

In addition to the deficiencies marked by *A*, deficiencies marked by the genes *B*, *Lg*, *J* and *G* have been found among plants produced by the use of treated pollen. Like the genes for endosperm characters the genes for plant characters differ in frequency of loss. Of the genes listed, *B* appears to be lost most frequently. Plants deficient for these genes also are characterized by at least 50 per cent pollen sterility.

Selfed progeny may be obtained only rarely from deficient plants. This is true especially of the extremely defective plants previously reported, since their vigor is so greatly reduced that even under the very favorable growing conditions provided, seed production is rare. Some of the deficient plants recognized by the use of markers are sufficiently vigorous to permit seed production more readily, but the progeny of most of these plants has not yet been grown.

The progeny of the defective plants is normal in vigor and fertility. Progenies have been grown from only four defective plants thus far, and it is possible that further experience may yield exceptions to this generalization. Each of the four plants produced at least 50 per cent aborted pollen. Two of them occurred in cultures in which *J* and *G* were used as markers; one a japonica plant indicating deficiency of a region including *J*, and the other a golden plant indicating deficiency including *G*. The progeny of these two plants, though vigorous and fully fertile, showed the same recessive characters as their defective and semi-sterile parents.

The explanation probably is as follows: The original defective plant is deficient for a portion of the normal gene complement. The absence of these genes, while more or less injurious, is not lethal to the diploid sporophyte, for the allelomorphs of the missing genes are present. But in the haploid gametophyte the absence of this group of genes is lethal. If the deficiency is limited to a single chromosome, half of the microspores and megaspores receive a deficient set of genes at meiosis; if two chromosomes are affected three-fourths of the spores are deficient, etc. The remainder of the spores receive a complete set of genes, and produce normal, non-deficient gametes. Since the selfed progeny is produced entirely from these gametes, it is normal in vigor and fertility, and is homozygous for the allelomorphs of

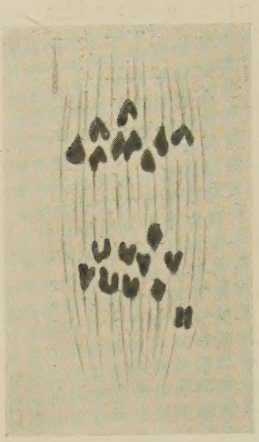

Figure 5.

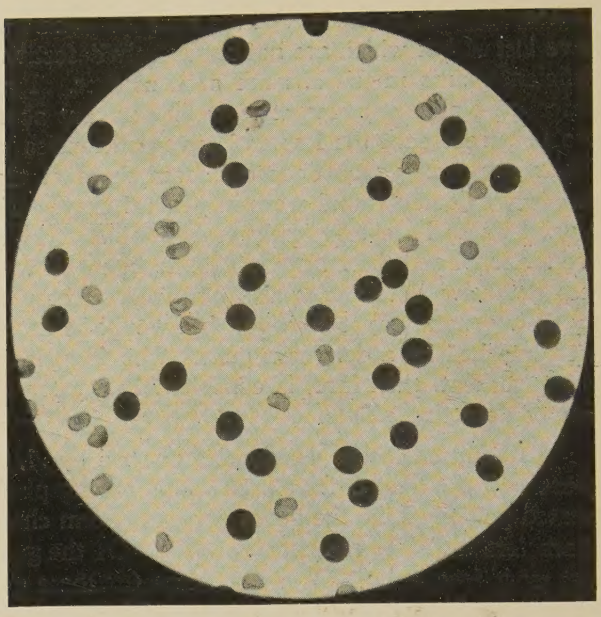

Figure 6.

Figure 5. Anaphase I in a defective plant with 19 chromosomes. (Randolph).
Figure 6. Pollen of a semi-sterile plant.

the deficient genes. Thus the deficiencies eliminate themselves in a single generation.

While deficiency appears to be lethal to the gametophyte, it is not necessarily lethal to the gamete when induced shortly before fertilization, as the experiments with pollen treatment demonstrate. The mature pollen grain contains three nuclei, the vegetative or tube nucleus and the two sperms produced by the division of the generative nucleus. In maize this division occurs several days before the pollen is shed. When mature pollen is treated, each of the three nuclei is affected independently. Induced losses of *A*, determined in the embryos and endosperms of the same seeds, show clearly that there is no correlation in the effect of the two sperms. Since the pollen grains carrying the affected sperms function in fertilization, it appears that the gametophyte is not seriously injured by a deficiency induced in one or both of the sperms. Even when the treatment is applied as much as 10 days before pollen shedding, deficiency may be transmitted by the pollen. Treatments applied at this stage affect the endosperm and embryo of the resulting seed similarly, and presumably represent effects on the undivided generative nucleus, transmitted by a pollen grain with an uninjured vegetative nucleus. When the treatment is applied to the tassel before maturation, a large proportion of the pollen is aborted and defective plants are not found in the progeny. Presumably deficiencies induced at this stage are eliminated in the gametophyte generation, as in the case of deficient plants.

*Transmissible partial sterility.*—Another type of partial sterility is induced by irradiation, a type distinguished from that found in deficient plants by the fact that sterility is transmitted to succeeding generations. In pro-

Figure 7.

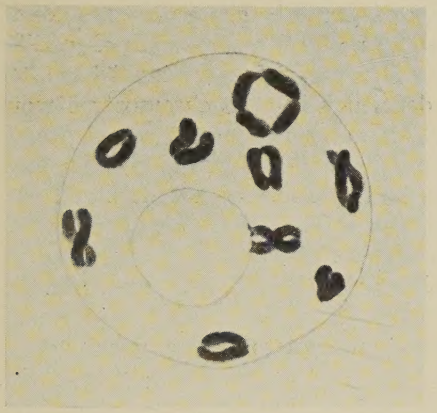

Figure 8.

Figure 7. Ears of semi-sterile plants (left) and normal sibs (right).

Figure 8. Diakinesis in a semi-sterile plant (Randolph).

genies produced by the use of treated pollen (for example the plants grown from the seed shown in figure 2) there occur a number of partially sterile plants which are fully normal in development, in addition to the partially sterile defective plants previously described. In many of these the proportion of the pollen aborted is approximately 50 per cent. A smaller number of plants abort approximately 75 per cent of the pollen, and other ratios also may occur. Commonly the aborted pollen is somewhat reduced in size and is almost empty, but in some plants it has partially developed contents. Several fairly distinct types of aborted pollen may be recognized in different partially sterile plants.

Plants which abort half of the pollen also abort half of the female gametophytes. Typical pollen of a semi-sterile plant is shown in figure 6. Typical ears of semi-sterile plants and of their normal sibs are shown in figure 7. In the semi-sterile plants at least half of the ovules, scattered at random over the ear, are sterile. This occurs whether the ear is pollinated by a semi-sterile or by a normal plant. The ears of normal plants by semi-sterile pollen produce a normal set of seed.

Most of the semi-sterile plants of normal vigor transmit semi-sterility to their progeny. About half of the progeny of these plants is semi-sterile. whether the semi-sterile parent is self-fertilized or is crossed, as male or female, with a normal sib or unrelated normal plant. In the semi-sterile progeny of plants producing distinct types of aborted pollen the same types are reproduced. The normal plants of progenies segregating semi-steriles give only normal progeny.

This is the mode of transmission characteristic of semi-sterility in the cases studied in the velvet bean by Belling (*1*) and in maize by Brink (*2*) and Burnham (*3*). Belling has shown that the transmission of semi-sterility may be accounted for by two complementary genes, but suggests as a more probable cause the interchange of segments by two non-homologous chromosomes. This would make each of the two chromosomes deficient for a section, which would be replaced by the section lost by the other chromosome. With normal segregation half of the gametophytes produced would have one or the other of the modified chromosomes, and would be aborted because of the deficiency. One-fourth of the gametophytes would receive both unmodified chromosomes and would be unaffected. The other fourth would have both modified chromosomes, and since the deficiency in each chromosome would be compensated by the section added to the other, these also would produce viable gametes. But these gametes (comprising one-half of the viable gametes of the semi-sterile plant) would contain the modified chromosomes, and when united with gametes of the unmodified type they would produce semi-sterile plants. Brink (*2*) has pointed out that simple translocation of a chromosome segment, without the reciprocal translocation involved in segmental interchange, would yield the same genetic results, on the assumption that sectional duplication as well as sectional deficiency is lethal to the gametophyte.

There is no doubt that transmissible semi-sterility induced by irradiation is generally due to a chromosomal change rather than to gene mutation. Any assumed change in two non-homologous chromosomes, which would make either chromosome lethal to the gametophyte unless accompanied by the other, will fit the breeding behavior. A mutant gene in each of the two chromosomes conceivably might have this effect, but the origin of semi-sterility would then require coincidental mutation of the two genes in each of the very large number of separate occurrences. It is much more probable that a translocation induced by irradiation is responsible, for any translocation affects two chromosomes, the one which loses and the one which gains the translocated segment. Moreover, as previously reported, Randolph has found a chromosomal irregularity associated with partial sterility. In the first meiotic division, in many of the plants examined, four of the twenty chromosomes are associated in a single complex, instead of in two pairs (figure 8). At diakinesis these form a ring, or in some cases an open chain. In a few plants there are similar complexes of six or more chromosomes, two complexes of four chromosomes each, or other modifications. All of the plants in which these complexes were found proved to be partially sterile, while all the plants found normal in meiotic behavior were normally fertile. The four-chromosome complex appears to be typical in semi-sterile plants. It is thought to be due to the conjugation of two chromosomes which have been

modified by translocation, with their unmodified mates, since one or both of the unmodified chromosomes would be homologous to portions of both of the modified chromosomes. Translocations involving more than two chromosomes would lead to enlarged or multiple complexes and to higher percentages of sterility. Burnham (*3*) has recently reported similar configurations in three semi-sterile lines of spontaneous origin, and has discussed their relation to partial sterility.

Whether the translocations responsible for partial sterility are simple or reciprocal is not yet known. It is possible that both may occur. The assumption that simple translocation is more likely to occur is hazardous in the absence of any knowledge of the mechanism responsible for the change. The lethal effect of sectional duplication, which must be assumed in accounting for semi-sterility by simple translocation, is certainly not general in maize, for the trisomics obtained from triploids by McClintock (*4*) demonstrate the functioning of gametes with various entire chromosomes reduplicated. These would be more unbalanced than gametes with only reduplicated portions of the same chromosomes. However, there may be certain chromosome sections which are lethal when reduplicated. The cytological evidence, showing that chromosome rings occur much more frequently than chromosome chains in the partially sterile plants, also suggests, although it does not prove, that interchange rather than simple translocation is the usual cause of semi-sterility. On the hypothesis of segmental interchange, the abortion of germ cells in transmissible semi-sterility, as in the non-transmissible semi-sterility of deficient plants, is a direct consequence of deficiency in the haploid gametophyte.

Semi-sterility in plants of apparently normal vigor is not always transmissible. Several cases have been found in which the semi-sterile plant, whether selfed or crossed, yields progeny of normal fertility. This result might be ascribed to a mutant gene lethal to the gametophyte; but, since we have seen above that some of the deficiencies induced have no effect on vigor and are recognizable only by the use of marker genes, it seems more probable that these plants represent similar minor deficiencies which do not happen to include a marked locus. Such plants are phenotypically indistinguishable from the semi-sterile plants resulting from translocation. In other words, the classification of plants as defective and normally vigorous semi-steriles does not coincide exactly with their classification as the result of deficiency or translocation, because the degree of sporophyte defectiveness due to deficiency varies beyond the limit of detection.

### Effects of Treatments Applied after Fertilization

Chromosomal effects are clearly shown also when the radiation is applied shortly after fertilization. The chromosomes derived from both parents are thus exposed to treatment in the young embryo and endosperm. Dominant marker genes are used as in the experiments with pollen treatment, and these may be brought into the heterozygous embryo by either the male or the female parent. Since the triploid endosperm nuclei contain two sets of chromosomes derived from the female parent, the loss of a single maternal chromosome carrying a dominant gene does not prevent development of the

dominant character. In the endosperm, therefore, the dominant markers must be provided by the male parent.

The usual technic is as follows: Before pollination the silks are cut back to a short brush to reduce variation in the length of silk to be traversed by the pollen tube. Pollen is applied from a plant of suitable genetic constitution, and the ear is irradiated 28 hours after pollination. The total intensity of radiation applied is usually about 500 *r*. Higher doses materially reduce the set of seed. In some experiments treatments have been applied similarly at later stages, the interval after pollination ranging from two to fifteen days. Under average conditions at Columbia fertilization occurs 21 to 24 hours after pollination.

The effect on the endosperm of treatments applied shortly after fertilization has been described in earlier papers (*7, 8*). Dominant characters derived from the male parent are lost as in the experiments with pollen treatment, but the tissue affected is limited to a portion of the endosperm. The endosperms affected are therefore chimeras, with definitely outlined sectors lacking some dominant characters present in the remainder of the endosperm. These sectors are irregular in form and vary in size from more than half of the volume of the endosperm to barely visible spots. When the treatment is applied 28 hours after pollination most of the sectors include one-eighth to one-half of the volume of the endosperm. As the interval between pollination and treatment increases, the size of the sectors decreases, and when the treatment is applied 8 to 10 days after pollination the individual sectors are barely visible. Later treatments have no visible effect on the endosperm.

The evidence for the chromosomal nature of these losses is derived from trials with the *C-Sh-Wx* group of linked genes, and is similar to that given for deficiencies induced by pollen treatment. About two-thirds of the losses of *C* involve *Sh* and *Wx* also, and, among the sectors large enough to permit the detection of shrunken endosperm, most of the remainder involve *Sh*. Moreover, although many losses of *C* without *Wx* occur, no loss of *Wx* without *C* has yet been found. This may mean that the *Wx* locus is nearer the point of spindle fiber attachment. If a break in the chromosome results in the loss of the portion no longer attached to the spindle fiber, and if *Wx* occupies a locus between *C* and the point of fiber attachment, breaks between *C* and *Wx* would cause a loss of *C*, while breaks on the other side of *Wx* would cause the loss of both genes.

Endosperm chimeras occur also in untreated material, though with much lower frequency. The spontaneous occurrence of chimeras has been studied in large populations as a basis for the determination of the effect of irradiation. Chimeras have been found for all endosperm genes previously mentioned in this paper. Under uniform conditions the frequency of loss of different genes varies rather widely. For example, in several strains of *r su* pollinated by *R Su* the average frequency of chimeras for *R* was more than 6 per thousand, while that for *Su* was less than 2 per thousand. Chimeras for other genes studied varied in frequency from 2 to 9 per thousand. Irradiation greatly increases the frequency of loss of all of these genes.

Among the plants grown from seed irradiated 28 hours after pollination, defective plants and semi-sterile plants similar to those resulting from pollen

treatment are found. When genes for plant characters are used as markers, deficiencies are found of chromosomes or chromosome sections derived from either parent. The description of deficiency and transmissible semi-sterility in the preceding section applies to these cases as well as to the cases resulting from pollen treatment.

Genetic changes induced by the treatments applied 28 hours after pollination apparently affect the entire embryo, although they usually affect only a part of the endosperm. Even when the treatment is applied 48 hours after pollination, an induced deficiency still affects the plant as a whole, although the deficiencies induced in the endosperms of the same seeds affect only small fractions of the endosperm. This indicates that the cell lineage of the entire plant, or at any rate of all visible overground portions, traces back to a single cell at this stage of embryo development. Treatments applied six days after pollination produce chimeras in the resulting plants, the portion showing the recessive character being distributed usually in several stripes, which together may cover as much as one-fourth of the entire plant surface. When treatments are applied later the average proportion showing the recessive characters is considerably reduced, although among several plants treated at the same stage of development the porportion affected may vary widely. A change induced by treatment applied to the mature seed affects a fraction of the plant not much smaller, on the average, than that affected by a change induced fifteen days after pollination. This is due to the differentiation of a growing tip early in the development of the embryo. Chimeras with sectors marked by distinct genetic characters, resulting from deficiencies induced at known stages of embryogeny, provide favorable material for the study of cell lineage in plant development. Sectors with genetically marked deficiencies, when they extend into the inflorescences, are in all cases partially sterile.

### Types of Chromosomal Variation Induced by Irradiation.

These results indicate that rearrangements and losses of portions of the chromosome complement occur with very high frequency as a consequence of X-ray treatment. The proportion of partially sterile plants following heavy treatment of mature pollen or very young embryos is sometimes as high as one-third. Most of these are partially sterile because of translocation, but a small proportion (roughly 15 to 25 per cent.) are due to deficiency. In addition there are many deficient individuals which are eliminated before the flowering stage, and which therefore are not included in this count. If germless seeds may be ascribed to deficiency, the frequency of deficiency is at least equal to that of translocation among the zygotes produced by the use of treated pollen. The endosperm evidence indicates that the frequency of deficiency is extremely high, for with markers on only 5 of the 10 chromosomes and with each chromosome marked at only a single locus, moderately heavy treatment of pollen yielded more than 20 genetically marked deficiencies per hundred endosperms.

Many of the induced deficiencies are unexpectedly "long." For example, the region *C-Wx* which is very frequently deficient in the endosperm is about 25 units long, and the region *R-G* which has been found deficient in the sporophyte is about 20 units long. The deficiencies which include these regions may of course be much longer. The absence of entire chromo-

somes is not rare among defective plants resulting from either pollen or embryo treatment. The survival of sporophytes which have lost so large a fraction of the normal gene complement is surprising. There are also deficiencies of more extreme effect which do not permit survival, and less extreme deficiencies which do not prevent normal plant development. There may be still less extreme deficiencies which do not eliminate the gametophyte, and which therefore do not cause partial sterility, but no indication of these has yet been found.

Deficiency and translocation are closely related. Their genetic effects are compared diagramatically in figure 9. For simplicity, deficiency is here represented as resulting from the loss of a chromosome section in the treated gamete. It is probable, as indicated by the discussion of recovery, that the affected section is not actually lost by the gamete irradiated, but is so affected that it is lost in subsequent cell division. For the purposes of the diagram the effect is the same. Similarly translocation is represented simply as the transfer of a section from one chromosome to another, although it is probable that the translocations actually occurring are usually reciprocal. The effect of simple translocation is the same as that of reciprocal translocation if it be assumed that section duplication as well as sectional deficiency is lethal to the gametophyte.

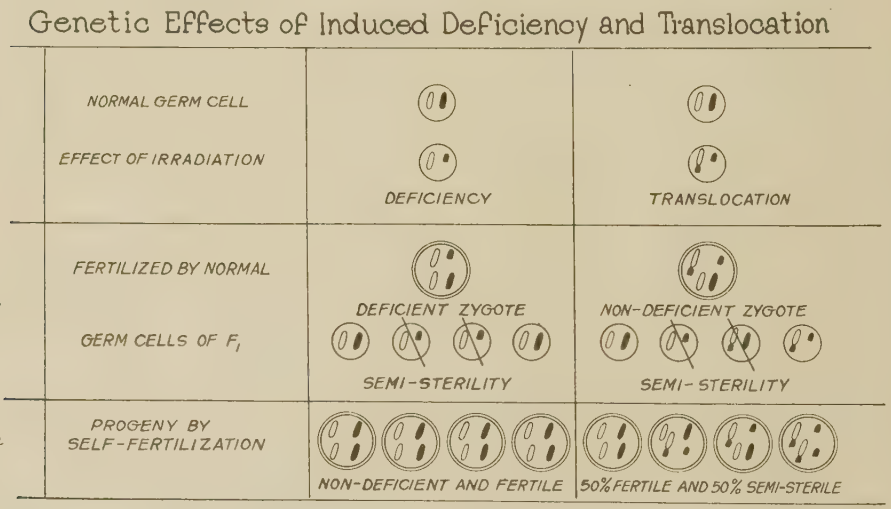


Figure 9. Scheme for genetic effects of deficiency and translocation. (Explanation in text).

In both deficiency and translocation a part of a chromosome is separated from the remainder, but in deficiency this section is lost, while in translocation it becomes attached to another chromosome or section. The deficient gamete, crossed with normal, produces a deficient zygote, which may or may not be defective in development. If it produces germ cells, half of them will be deficient and half of them normal. The deficient germ cells are aborted, and the selfed progeny, derived entirely from the unaffected germ cells, is wholly normal. On the other hand, the irradiated gamete in which two chromosomes have been modified by translocation, when crossed with

normal, produces a zygote with the normal gene complement, and therefore a plant of normal development. At meiosis random segregation of the two modified chromosomes and their unmodified mates produces four types of germ cells, two types which will be eliminated because of deficiency or duplication, and two types of functional germ cells with a full set of genes. One of the types of functional germ cells contains the two unmodified chromosomes; the other contains the two chromosomes modified by translocation. In the selfed progeny therefore this modification of the chromosomes segregates in a 1:2:1 ratio, one part homozygous for the modified chromosomes, two parts heterozygous (and therefore semi-sterile like the $F_1$ plant) and one part homozygous for the unmodified chromosomes.

The essential difference between deficiency and translocation is that deficiency eliminates a part of the gametophyte generation without affecting the surviving germ cells, while translocation not only eliminates a part of the gametophyte generation, but modifies a portion of the surviving germ cells so as to transmit the condition responsible for partial sterility. The diagram represents only the basic phenomena; in irradiated cultures various modifications and combinations of these may occur. Deficiency may involve a section of an entire chromosome, and may be single or multiple; translocation, whether simple or reciprocal, may involve one or more transfers or interchanges; and combinations of deficiency and translocation also may occur.

The experiments were designed to detect also certain other types of chromosomal irregularities. X-ray treatment might, by interrupting mitosis, cause doubling of the chromosomes, producing diploid germ cells or tetraploid somatic cells. This would be most effectively detected and utilized in the treatment applied shortly after fertilization, for tetraploidy induced at this stage would affect the entire plant. The plants treated at this stage were heterozygous for a number of endosperm characters, representing 3-6 linkage groups. Tetraploidy would be readily detected by the modified ratios for endosperm characters of the selfed ears, and might be indicated also by gigantism of the affected plant. About 1000 plants treated at this stage have been grown and more than 600 have been selfed, but no indication of tetraploidy has been found.

Certain other chromosomal irregularities, notably duplication and chromosome attachment, might be detected by modified ratios for endosperm characters of the same ears. If deficiency of an entire chromosome is the result of non-disjunction induced in early embryogeny, corresponding cases of duplication of an entire chromosome should also occur. Duplication of a chromosome or chromosome section bearing a dominant marker gene would result in trisomic segregation. Trisomic ratios have not been found among these ears. This might be due to the failure of the plants affected to produce ears, since plants with entire chromosomes reduplicated were found by McClintock (*4*) to be defective in development. But none of the radiation-induced defective plants examined by Randolph (*6*) showed evidence of chromosome duplication, though several showed chromosome deficiency. Duplication therefore appears to be rare among the plants treated. Sectional duplication may be induced by radiation as a secondary result of translocation, and would then appear in the following generation.

Attachment of chromosomes bearing genes for endosperm characters would result in linkage of genes normally independent in inheritance, although crossing over might be so frequent that the linkage would not be detected. Similar abnormal linkage resulting from translocation of a chromosome section would be associated with semi-sterility. A few cases of apparent linkage between genes normally independent have been found in fully fertile plants. These cases, which may represent the result of chromosome attachment, have not yet been analyzed.

It was expected that the use of X-rayed pollen would result occasionally in the production of haploids, for parthenogenesis might be induced by the action of the defective pollen. A few haploids have in fact occurred in cultures produced by the use of X-rayed pollen, but haploids have occurred also in cultures representing the effects of treatment at other stages. It is not yet certain that these are the result of the treatment. Although haploids have not previously been reported in maize, it is possible that they occur normally with frequency sufficiently high to account for the cases found.

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# REDUCING COSTS OF PRODUCTION BY MEANS OF MACHINERY *

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[Received for publication, January 28, 1931]

All men in professional agriculture must keep in mind the economics connected with their specialties, but the agricultural engineer, I feel, must be particularly careful that his conclusions are on a foundation economically sound. This is due perhaps to the fact that he deals with those things not directly capable of adding to the farmer's income. The animal husbandman buys a cow, for instance, which he can reasonably expect will add to his income by producing milk and more or less valuable offspring. The agronomist capitalizes the fact that, when given a reasonable opportunity, nature will return to him, at harvest time, a yield of grain or other crop many times as large as the amount of seed planted. The agricultural engineer, however, deals mainly with the equipment which is needed in the production of all sorts of products. He is a sort of mechanical consultant to the various branches of agriculture. He realizes, perhaps much more certainly than he is often credited with, the fact that a beautiful barn, (if there is such a thing as a beautiful barn), a tractor, a combine harvester or a plow of themselves never can add, in a direct way, to the farm income. All farm equipment must be classed among the indirect aids to the production of profits in agriculture and this thought is uppermost in my mind when considering the subject of farm machinery.

A glance over the history of agriculture on this continent will help us visualize the problems of the present. It was not until about 1890 that the binder found anything like general use on Ontario farms. When it did arrive it was put to work on the farms as they existed. It was the machine which brought harvesting operations to a higher plane of efficiency than was realized with the tillage machinery then in use. The binder made expansion in acreage per man possible.

One of the most important as well as perhaps one of the most unfortunate facts entering into a consideration of this subject is the fact that the size of farm unit we are taking for granted today is that size which was considered right for the family farm in the days when the ox was the best unit of power, when plows had wooden mould boards, when the only shallow tillage tool was the spike tooth harrow with iron teeth driven through wooden cross bars, and when hay was cut with the scythe and grain with the cradle. This period in our national development was the beginning of the steam age of industry but the use of the machine in our factories, or the age of "transferred skill" as it is called, had not yet destroyed the parity between the productive ability of agricultural and industrial workers.

When the binder became a machine of practical value on our farms it was hailed more as the deliverer of the harvest worker from the slavery of

*A paper read before the annual meeting of the Ontario Experimental Union, O.A.C., Guelph, January 7, 1931.
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swinging the cradle and hand tying of bundles than as a means of increasing the production per agricultural worker. Of course the binder hastened the clearing and bringing into production of the land of Ontario farms, enabling us to contribute to the tremendous surplus and price slump of the early nineties. The binder at the same time produced the incentive and released the labor necessary for the clearing of many thousands of acres on our farms.

For a period of perhaps 20 years after the year 1890 there existed what might be called a condition of good balance between the size of Ontario farms, the cost of farm labor and the possibilities of the worker to produce, in dollars' worth, more than he cost.

During this period the two horse team was the standard farm power unit, the single plow with the narrow, set-up furrow and shallow tillage tools of the two horse size were standard tillage units. The hundred acre farm with perhaps 80 to 90 acres of land under the plow could at that time be referred to as a very desirable size of farm unit which provided employment for 2 men, if not for the whole year then for at least 9 or 10 months of the year.

Toward the end of the period just referred to, however, efficiency in industry was gradually creeping ahead of that in agriculture. The steam age was at the height of its perfection about 1910 and electric power was beginning further to increase the efficiency of the factory worker. City wages increased and there occurred an increasingly large exodus of agricultural workers to the cities. This caused an increase in farm wages.

This increase in efficiency on the part of the agricultural worker was at first a gradual development. From 1891 to 1911 the number of acres cultivated per man increased from about 22 to over 32. That the movement was accentuated in the next decade is shown by the fact that during this period the acreage per man increased from 32.7 to 57.3 in 1921. (*1*) A similar trend in the increase of the efficiency of the farm worker in the United States is recorded. In 1850 there were 22.8 acres per agricultural worker; in 1920 this had increased to 46.1 acres per worker. The agriculture of that country in 1850 supplied 108 work units per worker, in 1890 there were 173 work units per worker and in 1920 there were 231 units per man.(*6*) Thus in seventy years the efficiency of the agricultural worker was more than doubled and the greatest increase occurred during the last 20 years of the period.

Then came the war, and during those hectic four years the 2 man farmer learned to operate as a one man concern while the 200 acre farmer who used to hire 2 men managed to get along with 1 man or a boy. It was done under the pressure and necessity of war and operators were buoyed up on the hope that after the war things would return to normal. We now know that after the war things refused to do this, however. And ever since then the Ontario farmer has been striving to adjust himself to the new conditions. At first he tried single handed to do the work of two men working harder and for more hours per day but still with two horse equipment or with such increases in sizes of tillage units as could be accomplished without the purchase of too much new and larger capacity machinery. The period of

deflation and depression following the war found the farmer in no financial condition to buy the new equipment he may have felt was needed.

In an effort to ascertain the trend in the use of tractors and other large scale machinery on Ontario farms during the last few years I sent to ten of the leading farm machinery firms of the province, a questionnaire asking for a statement of tractors, plows and other large scale machinery sold each year from 1921 to 1930. Seven of these firms filled out and returned the questionnaire. These firms include the largest firms in the business and it is likely that well over 80 per cent of the total tractors and other machinery sold from 1925 to 1930 is included in the accompanying chart.

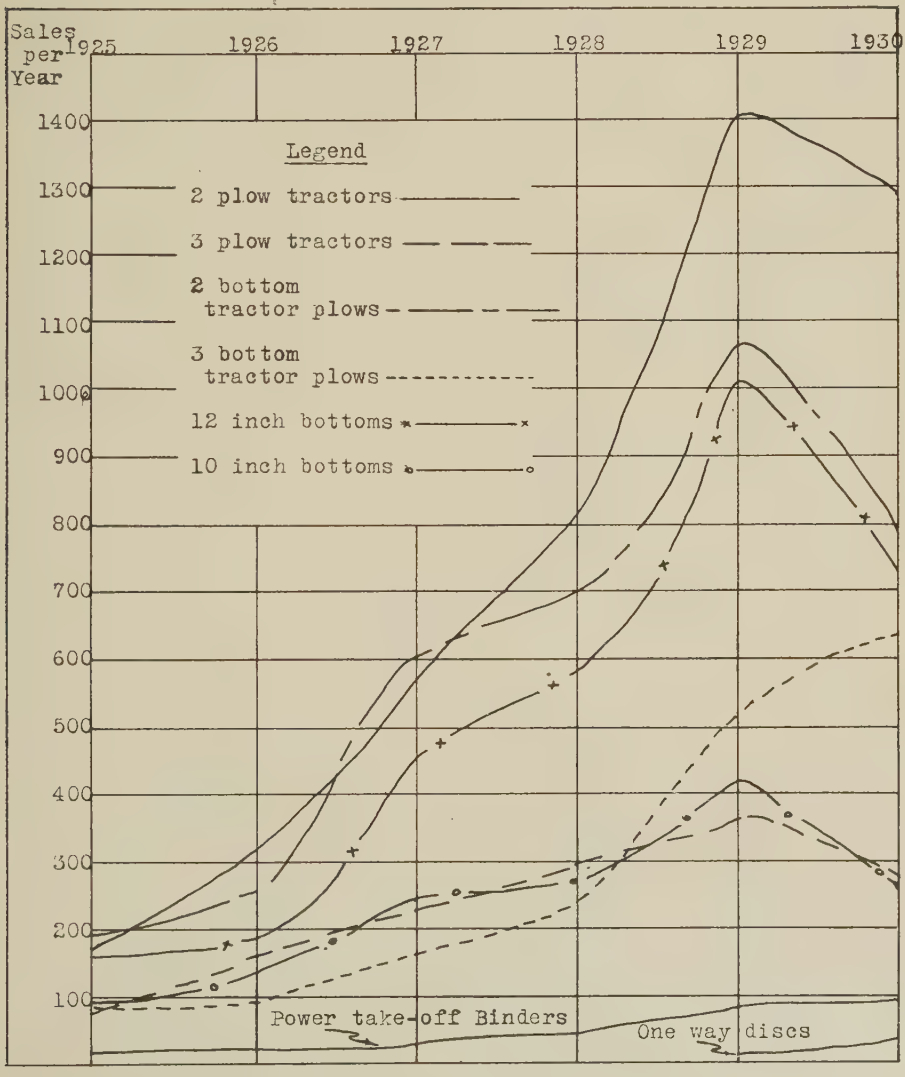



Figure 1. Trend of sales chart of tractors and large scale farm machinery in Ontario 1925-30.*

*From information furnished by seven farm machinery firms in answer to questionnaire Dec. 1930.

I am indeed grateful to these firms for the coöperation they so readily tendered and for the statements of individual sales of various kinds of machinery which they supplied.

Figure 1 shows that as soon as his financial condition permitted it, the Ontario farmer turned to mechanical power and larger machinery to help him overcome the labor shortage and high wages prevalent from 1921 to 1929.

In 1926 there were sold in Ontario, by seven firms, 320 two plow tractors. In 1929 the sales of this size of machine were 1410, an increase of 441 per cent. Total sales of two and three plow tractors in 1926 were 460 while in 1929 total sales were 1770, an increase in three years of 385 per cent. Though sales did drop off considerably during 1930, this decrease is not nearly so large as might be expected when the drastic decline in the prices of farm products is taken into consideration. The marked increase in tractor and power machinery sales since 1925 is, I believe, an indication of the realization, by the Ontario farmer, that only by increased production per man, accomplished by the use of more power per man, can he hope to master his present problems.

Painful though it was, without doubt, there has been a substantial increase in the production per man engaged in farming in Ontario and Eastern Canada generally. So far it has been accomplished, however, by overwork on the part of farm owners and their wives, by the enforced neglect of repairs to buildings and things which make for good appearance on farms and farm homes, by the practice of only the bare necessities of tillage operations, and by the elimination of hoed-crops from the cropping programme. Due to improved business conditions and rising prices between 1925 and 1929, prosperity returned and Ontario farmers not only shared in this prosperity but succeeded in affecting a considerable adjustment to post war conditions.

Then came the years 1929 and 1930 with the disastrous drop in wheat and other grain prices with an almost crippling decline of prices of all other farm products. The western farmer without question is in bad shape and it is hard to say what the easterner's condition is until there has been time to size up the situation a little better.

## The Farm Profits Formula

The profits to be made from any kind of farming can very well be expressed by the following simple formula, $N = (G—C)$, where $N$ = profits or net income, $G$ = gross income, and $C$ = costs of production. The reduction in costs of production by machinery, which is the subject in hand, becomes much more important, I feel, if dealt with in terms of N than in terms of C. It is true that C represents more items in production costs than those due to the operation of mechanical equipment on our farms, but for our consideration we must consider the effect on N of a reduction of that part of C which can be affected by the factor described in the subject, the other factors making up C remaining constant.

This formula is well worth a moment's consideration in its entirety before concentrating our attention on the C factor. The term (G—C) can also be said to represent the possible margin in any agricultural enterprise. Expressed in percentage of G, or the gross income, the term (G—C) is invariably small.

Today the N factor represents more than ever before the standard of living possible on our farms. It represents the possibility of the realization of such dreams as "a bathroom in every farm home", "electric light and power installation on every farm", and "a secondary school education for all farm children". Since the relationship between G and C is a fairly close fixture at all times it becomes evident that while the reduction of the C factor is important, what is needed almost universally in Ontario and eastern Canada generally is a larger G factor. The gross income on the average farm is the biggest obstacle to the realization of a satisfactory standard of living as well as to the efficient use of the best in present day machinery.

Then there is the problem of volume of production. There is plainly a surplus of agricultural products, especially of cereals and dairy products and it is folly to talk of increased production at this time. Yet for the individual worker engaged in the industry nothing is more important than increased output. The only way, then, to satisfy this paradoxical demand is not so much to increase the output per farm as it is to increase the output per unit of cost and since labor is the most expensive item entering into these costs this boils down to producing more per worker. It is here that the more effective or efficient use of farm equipment of all kinds comes in.

The problem of increasing our efficiency in the use of farm machinery divides itself into two parts or phases. First, there are the possibilities of greater efficiency in the use of tools now available, and secondly, the possibilities of reducing production costs by the use of new kinds of equipment not now well known. The first of these phases presents perhaps the larger field of endeavor toward improvement and I should like to suggest the need for concentration on the following possibilities:

1. The need for larger family farm units.
2. The possibilities of spreading peak power and tillage loads.
3. The necessity for increased labor efficiency.
4. Increased efficiency through a higher quality of work.

## 1. Larger Family Farm Units

When we turn to the first of these points it is necessary again to bring out the formula N = (G—C). No matter how efficiently a business is run, or, in other words ,even with the margin between gross income and costs of production larger than the average, the factor governing net profits, or N, is gross income. Wherever cost of production surveys have been conducted it is brought out that the largest labor incomes are made on farms having a size of business as large as or larger than the average for the type of farming under consideration.

Tables 1 and 2 taken from New York State farm surveys show plainly that for a large labor income there must be a large unit of production. The productive work unit is used here because it is a very reliable way of measuring the size of the productive organization of a farm. The relationship between size of business and labor income is very well brought out in the farm surveys made in Ontario. (*2*) Here Professor Leitch says, "It will be noted . . . . that the non-productive capital—money invested in buildings and machinery—is 42 per cent of the total capital on the small farms but decreases to 29 per cent of the total capital on the largest farms."

TABLE 1.—*Size of business related to labor income. 670 Jefferson County farms, 1910. A dairy and hay region,* *

| Grouped by Productive work units | Number of farms | Productive work units | Labor income | Per cent over $1,000 |
|---|---|---|---|---|
| 100 or less | 22 | 78 | $ 36 | 0% |
| 101 - 200 | 61 | 156 | 193 | 0 |
| 201 - 300 | 126 | 256 | 416 | 6 |
| 301 - 400 | 134 | 347 | 516 | 7 |
| 401 - 500 | 120 | 446 | 663 | 28 |
| 501 - 600 | 86 | 545 | 730 | 30 |
| 601 - 700 | 60 | 640 | 981 | 48 |
| 701 - 800 | 27 | 742 | 1035 | 59 |
| Over 800 | 34 | 991 | 1311 | 68 |

* From Cornell University Farm Survey Records.

TABLE 2.—*Size of business related to labor income. 578 Livingston County farms, 1908. A general farming region,** 

| Grouped by Productive work units | Number of farms | Labor income | Per Cent over $1,000 |
|---|---|---|---|
| 100 or less | 11 | $ 85 | 0% |
| 101 - 200 | 65 | 212 | 3 |
| 201 - 300 | 131 | 338 | 8 |
| 301 - 400 | 115 | 533 | 21 |
| 401 - 500 | 81 | 727 | 30 |
| 501 - 600 | 70 | 919 | 49 |
| 601 - 700 | 25 | 894 | 44 |
| 701 - 800 | 14 | 1115 | 50 |
| Over 800 | 66 | 1592 | 62 |

* From Cornell University Farm Survey Records.

A very important measure of the size of a farm business in the final analysis is the value of products marketed. Some small farms may be used as ordinary dairy farming or mixed farming establishments but the operator may establish a strong sideline in poultry, bees or a cash crop, thus adding considerably to his size of business, which, by the way, is one form of expansion not infrequently met with. Analysis of such a business may reveal, however, that the farm proper is not a profitable enterprise or that the sideline is carrying the farm, probably because the farm is not large enough to justify investment in the smallest size of large scale tillage and harvesting equipment available today. I am referring now to the farm having not more than perhaps 50 or 60 crop acres.

By the smallest size large scale farming equipment I mean equipment to go with a two plow tractor or one of about a 10-20 rating or a set of tillage machinery to go with 4 and 5 horse teams. This would include a two furrow tractor or horse drawn gang plow, a 7 or 8 foot tandem or double disc harrow or its equivalent in a single disc harrow, a stiff-tooth tractor cultivator, a 9 or 10 foot seed drill and 20 foot drag harrow. Such an outfit represents an original outlay of probably $1800. The investment in machinery on 76 crop acre farms in eastern Canada averages $871.04 and this gives rise to an annual per acre charge of $2.85. (*3*)

*Two Men Minimum Labor Force*

This is a large item in the total cost of production and it comprises an overhead charge which should be spread over as large a number of crop acres as the available labor force on the farm can handle. The factor deciding the optimum size of farm to be operated with large scale machinery is the number of men to be employed. We hear a great deal about the one-man farm and such combinations as 100 acres, 1 man and a tractor. It must be admitted that one man is very much handicapped in the performance of many farm operations. Yet very many farms as now organized are not large enough units to be profitable 2 man units. Both from the standpoint of distribution of the fixed charges, due to the investment in machinery, and that of securing sufficient work for the profitable employment of the minimum number of men it is necessary to insist on a farm with a crop acreage larger than that of the 100 acre mixed farm. Just how large the minimum crop acreage should be depends somewhat on the type of farming carried on but I believe that with large scale tillage machinery and with land of topography and other qualities suitable to its use, two men should have no trouble taking care of 200 crop acres.

Large scale tillage units such as I have in mind simply increase the capacity per man in all tillage work. The trouble with the 2 horse unit during the recent past has been that at current wages a man could not earn what he cost by their use. At $3. a day, and that is what a man and his board should be worth, plowing an acre and a quarter a day means a labor cost for plowing of $2.40 an acre. This does not include the cost for power which at 12 cents per horse hour is equal to $2.40 a day for a two horse team; this figures out to $1.92 an acre making a total labor and power cost for plowing of $4.32 an acre.

Tables 3 and 4 show the capacities of various sizes of teams suitable for eastern Canadian conditions and also the costs per acre of doing tillage work in this part of the country.

TABLE 3.—*Acreages covered per ten-hour day (4).*

| Operation | Horses | | | Tractor | |
|---|---|---|---|---|---|
| | 2-horse team | 3-horse team | 4-horse team | 2-plough tractor | 3-plough tractor |
| Ploughing | 1.5 | 2.0 | 3.0 | 5.2 | 6.7 |
| Disking | 7.0 | 9.0 | 12.0 | 16.3 | 18.9 |
| Cultivating | 8.0 | 10.0 | 15.0 | 18.1 | 18.7 |
| Harrowing | 13.0 | 17.0 | .... | 26.5 | 26.8 |

TABLE 4.—*Costs per acre.*

| Operation | Horses* | | | Tractor | |
|---|---|---|---|---|---|
| | 2-horse team | 3-horse team | 4-horse team | 2-plough tractor | 3-plough tractor |
| Ploughing | $3.33 | $3.00 | $2.33 | $1.65 | $1.52 |
| Disking | 0.71 | 0.66 | 0.58 | 0.53 | 0.54 |
| Cultivating | 0.62 | 0.60 | 0.46 | 0.48 | 0.55 |
| Harrowing | 0.38 | 0.35 | .... | 0.53 | 0.38 |

*The value of horse labor has here been assumed to be 10 cents per horse hour.

The amount of land one man can take care of is governed by the capacity of the equipment he is using on the one hand, and the number of days available for doing the work in question on the other. This brings us to our second point—that of a consideration of peak loads. It is the height of the peak in our peak load periods which controls the amount of power which will be required to do the work in hand in the time given.

2. Power and Tillage Peak Loads Should be Lowered and Widened

Where the two horse team is the size of the tillage unit employed the usual 100 acre farm provides peak loads which most of us know from experience tax the ability of two such outfits to take care of them. The two man farm described earlier should be powered by not less than seven or eight work horses or by a tractor and a three or four horse team. Where all horse power is used more man labor will be needed on tillage work than where a tractor is used. Also, where 2 four-horse teams are kept the cost for power will be quite a considerable one. The average cost of keeping a team of horses for a year in New York State, according to the cost account records covering 119 horses on 34 farms, is just about $362.00 per year; this is for a two horse team. For our eight horse farm this would be $1448.00 per year for horse power. It is not likely that there is much difference between the costs of horse keep on the north and south shores of Lake Ontario. This does not look like a very favorable case for the superior economy of horse power, though present day feed prices will change the figures to some extent. On the other hand, the average cost of keeping a tractor going on 175 New York State farms in 1926 was $269.00 against $362.00 for two horses. The average hours of work per horse are 763 per year, which gives a per hour cost of 21.9 cents. (*5*)

The tractor can be depended upon to replace a four horse team on our optimum size, two man farm which means that it will immediately relieve the business of at least $600.00 a year in horse keep. The cost of tractor power depends very largely on the amount of use it gets. The latest survey covering tractor costs is probably that conducted by Dr. C. W. Gilbert in New York State in 1926. This survey covers 173 tractor farms and table 5 sheds some light on these costs. It will be noticed that by distributing the fixed

Table 5.—*Relation of hours of work per tractor annually to the cost per hour of operation—181 tractors on 173 farms* (*7*)

| | Hours of work per tractor annually | | | |
|---|---|---|---|---|
| | Less than 200 hours | 200 to 400 | 400 to 600 | 600 or over |
| Number of tractors | 54 | 85 | 26 | 16 |
| Average hours work per tractor | 134.7 | 280.6 | 482.9 | 812.8 |
| Per cent draw bar work | 71.6 | 81.6 | 75.6 | 73.8 |
| Cost per hour of operation* not including fuel cost or operator's wages | $1.10 | $0.60 | $0.47 | $0.34 |
| Cost of fuel per hour | $0.27 | $0.26 | $0.31 | $0.30 |
| Total cost per hour of use without operator | $1.37 | $0.86 | $0.78 | $0.64 |

* Note.—The items included under costs of operation, but not including fuel or operator's wages, are:—depreciation, interest, oil, grease, repair parts and experts' services, all labor needed to look after the machine outside of operating it, housing charge and insurance.

charges of interest and depreciation over as many hours of work as possible the cost per hour is very favorably affected, it being $1.37 per hour where the tractor was used 200 hours, $0.86 per hour where it was used for from 200 to 400 hours, $0.78 per hour where it was used 400 to 600 hours and $0.64 where it was used over 600 hours.

It becomes clear, therefore, that the kind of power to be selected should be governed largely by our peak loads of work for the farming year. The two-plow tractor can take care of much larger peaks than can a four horse team. (7) If kept going, say 20 hours per day, which is easily possible, it can replace two such teams. When the question is considered in the light of the above facts, however, it would appear that a more desirable power combination would be a tractor supplemented by perhaps a three horse team. As mixed farming is conducted in this province at the present time, the possibilities for the spreading of peak power loads are rather limited. Still something can be done in this direction if this factor is kept in mind when the cropping programme is planned. Considerable attention must be given to a choice of crops which will conflict with each other as little as possible during seeding and harvest periods. The fact that fall wheat is not sown in the spring and that its harvest period comes between haying and the cutting of oats and barley makes it a very desirable crop from the standpoint of spreading out peak loads.

The use of large scale equipment increases the capacity per man in the production of those crops which now produce our peak loads in seeding and harvest time. It is also possible in many cases to introduce a cash crop which fits into the cropping programme without too much conflict and which does not require too heavy an investment in special machinery. Such crops are table turnips, cabbage, and factory peas. In some cases potatoes also can be introduced but it should be mentioned that potatoes are a special crop for the most efficient production of which a considerable outlay in special machinery is essential. The minimum acreage justifying this investment is perhaps 20 or 25 acres.

It must not be forgotten, of course, that the removal of a portion of the total crop acreage from the hay and grain area for cash crops lessens the usual seeding and harvest peak loads. In addition to this, such crops add greatly to the size of the farm business and to the efficiency with which power and labor are employed.

In the days of the two horse team, the work of tillage occupied a much larger proportion of the available man work hours than it should have received. In those days the field work on our farms assumed the proportions of an end in themselves rather than a means to an end. The job of fall ploughing for instance on a 100 acre farm, when done with a single plow, was large enough to force the farm operator's attention upon itself by sheer magnitude. It is perhaps no wonder that some farm operators worry much more about getting their fall ploughing done than they do about turning the season's crop into money.

The tractor is a veritable glutton for work and completes astonishing tasks in very short spaces of time. This has the effect of releasing from

field work many man work hours which can be devoted to the preparation and sale of farm products. Live stock will receive more attention, farm building and equipment repairs, now so much neglected, can be caught up with and last but not least, the farm work day can be reduced to one of at least a more tolerable length. All this is possible in spite of a considerable increase in production per man.

### 3. Increased Efficiency in the Use of Labor

Man labor is generally dealt with as a separate item in efficiency analyses but the use of labor and that of our equipment are so closely connected that they have an important bearing on each other.

Just as the spreading, or wider distribution, of peak loads in field work results in the greater efficiency in the use of power sources, so a choice of enterprises which spreads the use of labor over as large a period of the year as possible usually means a larger gross income and hence larger profits.

Cost figures from New York state surveys show that the efficiency with which both man and horse labor is employed is one of the most important items in the control of profits. The yardstick used for the measurement of the amount of work for men and horses that any farm business supplies is called the "Productive Work Unit". These units are based on the amount of work a man and a horse can do in a 10 hour day, but without the use of large scale equipment. For purposes of comparison each acre of the various kinds of crop and each head of live stock are said to supply the business with a certain number of "productive work units" per year. Tables 6 and 7 give the "Productive Work Units" per year for crops and live stock found on our mixed farms.

Table 6.—*Productive work units per year for various crops.*

| Crop (per acre) | Man Units | Horse Units |
|---|---|---|
| Small grains, oats, wheat, barley, peas, etc. | 2 | 3 |
| Hay (per cutting) | 1 | 1 |
| Silage corn | 4 | 6 |
| Fodder corn | 3 | 5 |
| Potatoes (table stock) | 10 | 10 |
| Clover and grass seed | 1 | 1 |
| Field beans | 4 | 5 |
| Factory peas | 4 | 6 |
| Roots (mangels, turnips, etc.) | 15 | 12 |
| Commercial orchards | 15 | 8 |
| Berries | 20 | 5 |

Table 7.—*Productive work units per year for various livestock.*

| Livestock | Man Units | Horse Units |
|---|---|---|
| Ordinary dairy cows.....per cow | 15 | 2 |
| Purebred dairy cows.....per cow | 20 | 2 |
| To be added when milk is retailed.....per cow | 15 | 15 |
| To be added when certified milk is produced .per cow | 15 | 2 |
| Heifers, calves, bulls, steers, colts.....each | 2 | 0.1 |
| Breeding ewes and rams.....each | 0.5 | 0.05 |
| Other sheep or lambs fattened or wintered....each | 0.2 | 0.02 |
| Brood sows (and pigs till weaned)..... | 3 | 0.5 |
| Boars.....each | 0.5 | 0.1 |
| Other hogs raised.....each | 0.5 | 0.1 |
| Hens per 100..... | 20.0 | 2.0 |

TABLE 8.—*Productive work units of typical 100 acre farm.*

| Crops and Livestock | Acreage or Number | Man Units | Horse Units |
|---|---|---|---|
| Hay | 20 | 20 | 20 |
| Corn (silage) | 10 | 40 | 60 |
| Potatoes | 2 | 20 | 20 |
| Roots | 3 | 45 | 36 |
| Fall wheat | 15 | 30 | 45 |
| Spring grain | 22 | 44 | 66 |
| Dairy cows | 10 | 150 | 20 |
| Young stock | 10 | 20 | 1 |
| Calves | 6 | 12 | 1 |
| Sows and litters | 3 | 9 | 0.3 |
| Pigs raised | 26 | 13 | 2.6 |
| Hens | 100 | 0 | 2 |
| Total | | 423 | 273.9 |

Man equivalent 1.8

Horses 4

Productive work units per man $\frac{423}{1.8} = 235$

Productive work units per horse $\frac{273.9}{4} = 68.5$

TABLE 9.—*Productive work units of typical 200 acre dairy farm.*

| Crops and Livestock | Acreage or Number | Man Units | Horse Units |
|---|---|---|---|
| Hay | 40 | 40 | 40 |
| Silage corn | 15 | 60 | 90 |
| Potatoes | 2 | 20 | 20 |
| Roots | 7 | 105 | 84 |
| Fall wheat | 20 | 40 | 60 |
| Spring grain | 52 | 104 | 156 |
| Dairy cows | 22 | 330 | 44 |
| Young cattle | 18 | 36 | 2 |
| Calves | 10 | 20 | 1 |
| Sows and litters | 6 | 18 | 1 |
| Pigs raised | 40 | 20 | 4 |
| Hens | 100 | 20 | 2 |
| Total | | 813 | 504 |

NOTE.—Pasture acreage 25 rotational, permanent 15, woodlot 12, orchard and farmstead 7.

Man equivalent 2.25

Horse equivalent 7

Productive M.W.U. per man $= \frac{813}{2.25} = 361$

Productive H.W.U. per horse $= \frac{504}{7} = 72$

Tables 8 and 9 show the number of productive work units supplied by two typical Waterloo county farms, one of 100 acres and one of 200 acres. There are a few minor enterprises on each farm which have been neglected. Each has a small orchard, for instance; the 100 acre farmer has tried small fruits and has discovered how seriously these crops can conflict

with haying and fall wheat harvest. The 200 acre farmer has a small maple grove and owns a small evaporator which is not included in this analysis.

The 100 acre farm with this cropping system supplies a total of 423 productive man work units. He has hired help for somewhat over 9 months of the year and at this rate there were 235 productive m.w.u. per man. This is rather too low for the efficient employment of labor. The 200 acre farm supplied a much more favorable quantity of work. With a man equivalent of 2.25 for the year there were 361 p.m.w.u. per man. It is not to be inferred that the man on the 100 acre farm did not work as long hours as those on the larger place but they employed 2 horse units which made for the inefficient use of labor. What about buying a large scale tillage outfit for such a farm? It can be done and is being done but it has the following drawbacks:—

1. It places a heavy machinery charge on each acre of land.

2. The best that could be done is to save perhaps .5 of a man equivalent per year. This would make the place a one man establishment for a large part of the year which is not very satisfactory.

3. It does not make a suitable tractor unit since there are hardly enough days of work to take care of the overhead charges. Two horses would probably be kept which would mean a heavily over-powered farm. Doing custom work would probably be resorted to if this farmer bought a tractor.

The large farm, on the other hand, has the advantage on every one of these points. It has a high p.m.w.u. figure which may be interpreted by some to mean that each man works 361 days per year. Such is not likely the case, however, because with a tractor or the consistent use of 4 horse teams the man labor requirement per acre of crop can be cut considerably lower than that used in making the efficiency anlaysis. With a tractor it can probably be cut in half. The dairy herd also is of a very much more suitable size for the profitable use of mechanical equipment. A milking machine begins to be a real money saver only in herds of at least 16 milkers, and 22 is still more favorable. Here again some p.m.w. units can be saved.

Then there is the fact that a two man force is a more satisfactory unit for most jobs than a one man force, and there need be no hesitation at keeping the second man since there is enough work to use him profitably.

The larger farm also makes a more satisfactory tractor unit. Such a farm is likely to supply the tractor with at least 400 hours of work per year, which, as we have already seen, makes for a much more favorable operation cost than is possible on the smaller farm. This farm also has a large enough size to use profitably the 3 horse force which, in addition to the tractor, seems still to be desirable on the Ontario mixed farm.

When this question of the optimum size of family farm is carefully gone into I feel that the conclusion will almost invariably be similar to that which I have just presented.

It is doubtful whether the young man of the past gave the question of the matter of optimum size of farm much thought. Farm sizes are taken for granted by the people brought up on and among them. The dictates of custom even today are perhaps the strongest influence in many of our farm practices.

The man with the single furrow plow cannot compete with one using larger units.

Last summer I visited the section of Waterloo county in which I was raised. One farmer who had recently bought a new tractor did a beautiful job of after harvest cultivation with a one-way disc. He covered a 54 acre field in just a day and a half—less than 15 hours in fact—cutting everything loose and stirring the ground to a depth of 4 inches. His next door neighbor was doing similar work with 2 horses and a two furrow gang plow in a 20 acre field. After 4 days in the field he still had a considerable portion of it to do. The question such an observation provokes is, "How long can the man using only the power of a two-horse team hope to compete with his tractor using neighbor?" Human labor is the most expensive item entering into the production of farm crops and the greatest advantage in using large scale machinery is that it makes man labor more efficient. To capitalize these facts it is necessary, however, to spread the costs of both labor and equipment over larger producing areas. This brings out once more the need for larger family farm units.

### 4. Increased Returns Through a Higher Quality of Work

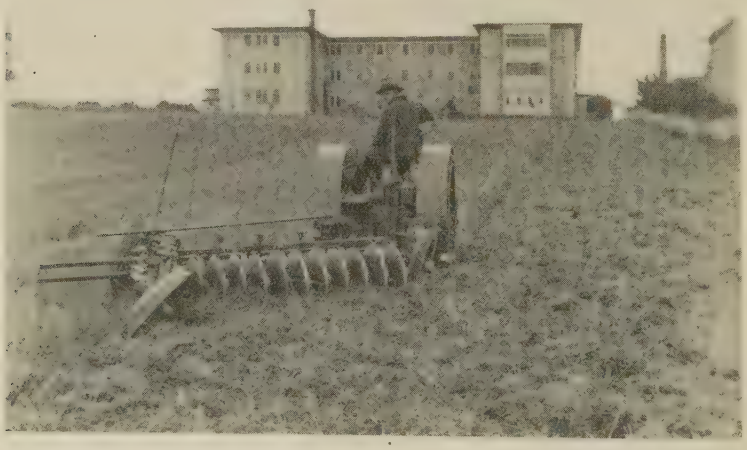
This brings us to the fourth of the possibilities for affecting reduced production costs through the more efficient use of machinery.

This possibility lies in the production of a higher quality of work with our mechanical equipment. One of the objections to the early tractor tillage work was that it was not of as good quality as that done by horses. And there was truth in that statement. Today this is no longer the case. The tractor has made possible, in fact has demanded, heavier tools with better penetration than horse tools ever had. This is particularly true of shallow tillage machinery. The draw-bar power of the tractor is much more positive and more plentiful than that of horse power. There is not the same tendency on the part of the operator to ease the cultivator or disc out of the ground when

a tractor is used as is the case with horses. Good teamsters are the only kind wanted on farms using horses and they are usually sufficiently sympathetic to make the work they are doing no heavier than absolutely necessary. Then, also, when ground is dry and hard, horse drawn shallow tillage tools have never had enough weight for good penetration. Yet it is when soil is in this condition that shallow tillage is most effective in weed eradication. It is for this work that the power of the tractor, the extra penetration and weight of tractor harrows and cultivators, the greater speed of the tractor and the fact that it is not affected by the weather all give the tractor using farmer a tremendous advantage.

The tractor also has had a beneficial effect on the choice of plows in Ontario. There is probably no place on the North American continent where people have so tenaciously stuck to the narrow cut plow with the set-up furrow as they have in Ontario and Quebec. To turn a furrow 7 inches deep and only 9 inches or 10 inches wide is not an easy matter; the plow must lean at just the right angle to set this shape of furrow up properly or it will roll back. The narrow furrowed tractor gang plow of two or three furrows is a rigid frame machine; if the ground slopes away a little from the furrow all three plows will be leaning slightly away from their work. Immediately there is a tendency for the furrow slice to roll back. Much of this tendency is due entirely to the nearly square shape of the furrow. Its use makes plowing harder and there is no advantage in it. The 12 or 14 inch plow costs less per unit of width, takes less power in operation per square inch of furrow slice turned, is easier to operate, covers trash more thoroughly than does the narrow furrow plow and in every other way does as good work as the much praised narrow cut plow. Why then should we continue to use 3 furrow 10 inch gang plows instead of 2 fourteens or 3 twelves?

It is interesting to note how deeply this love for the sight of narrow furrows is ingrained in Eastern Canadian farmers, especially so when we realize that it was developed for an entirely different set of farming conditions.



A "one-way disc" at work on Macdonald College Farm.

The narrow plow bottom is an old country development and grew out of the practice of sowing grain on ground plowed with narrow furrow, high cut plows. The sowing was done by hand, of course; then the seed was covered by knocking the combs off the furrows with a drag. Another idea behind the high cut furrow was to provide drainage, or to lift, as it were, the crop growing layer of soil out of the water. All of us know, however, that one of the most important things to us is to get a thorough contact between the furrow slice and the subsoil; that is why we do not favor spring plowing for shallow rooted crops and why we are so careful to thoroughly disc spring plowed land for corn.

Another reason for the narrow plow bottom is the fact that it makes a logical two horse load. It is plain, however, that it is no longer a profitable one-man plow.

The increased use of 12 and 14 inch plows while not a large factor is nevertheless an item which will help lessen the cost of production. The corn borer control investigations have done much to expose the weaknesses of the narrow plow and the superiority of the wider bottoms. It is a peculiar thing that on the 175 tractor farms in New York State studied by Dr. Gilbert in 1926 there was not one plow with less than 12 inch bottoms and there were only a few twelves; the rest were 14 inch bottoms. The land on the south shore of Lake Ontario is just like that on the north shore so far as I could see. Yet we continue to use 10 inch plow bottoms. I wonder why?

It is interesting to note the tendency toward wider plow bottoms as illustrated in the machinery sales trend chart, figure 1.

The necessity for greater efficiency in the use of human labor in our tillage work has never been more convincingly stated than in the words of Dr. Riddell, one of Canada's representatives to the League of Nations at Geneva in an article in the International Labor Review of March 1926, in which he says—

"The elimination of useless toil is not always easy; there is much that is of old standing in the way, old practices, even ideals, which in their day were of value. The ploughman, for instance, with his two-horse team has become almost symbolical, and a spectator, ignorant of agricultural mechanics, watching a field being ploughed by two, or three, such teams, might be pardoned, as he watched, for congratulating himself on witnessing a scene of so much honest toil. And yet he might be wrong. If conditions made it possible for one man alone to drive the two, or even three, teams of horses on a single "gang plough", then it were better for the drivers of the other teams were they lying under the shade of a neighbouring tree, smoking their pipes and enjoying a half-day's rest. As ploughmen their work would be wasted, because unnecessary. No toil is honest which can be done with less toil, nor can there be much excuse for a method of preparing the soil so wasteful of human effort."

*The Need for Farm Replanning*

Before the minimum size large scale tillage units can be most profitably employed on most Ontario farms a rearrangement of the fences is necessary. Research work has shown that the acreage per day which can be covered by a

3 or 4 horse team with various machines increases very rapidly as the size of the field increases until a field of about 18 acres is reached. This does not mean that 18 acres is the ideal size of field, however. Every farm is an individual problem from the standpoint of field arrangement and the best thing to do is to have a survey made and a map drawn after which rearrangement can be made, first on paper, then transferred to the land. In a general way it is a good idea to make as many fields as there are years in the rotation being followed. Then, where part of a field is needed for rotational pasture a temporary fence can be erected. This is much cheaper than the maintaining of the fences which are eliminated by the replanning of the place.

It is true that only a portion of the dairy or mixed farmer's work has to do with crop growing yet it is in this work that it is possible to bring about real increases in production per man by the use of machinery. Also it is the amount of crop produced which governs to a large extent the size of the farm business. It is not the intention to compare the acreage per man of Ontario farms with that of the Saskatchewan grain grower, yet it is of interest to look over the following table which shows the acreage cropped per man in the various provinces of this country.

TABLE 10.—*Area cropped per man by provinces* (7).

| Province | Acreage per man |
|---|---|
| Saskatchewan | 124.8 |
| Manitoba | 85.4 |
| Alberta | 82.5 |
| Quebec | 36.4 |
| Ontario | 34.9 |
| Prince Edward Island | 29.8 |
| New Brunswick | 24.9 |
| Nova Scotia | 16.4 |
| British Columbia | 10.3 |

These figures are averages and there are doubtless many farms too small for the profitable use of large scale equipment in Saskatchewan as there are in Ontario. It is doubtful, however, whether there are many two horse tillage units in operation in Saskatchewan. From the standpoint of efficiency in the use of power and labor, Ontario farms will, I believe, soon be divided into two classes: those which are too small to permit the profitable use of large scale machinery, and those of sufficient size to make its profitable use possible. The owner of the small farm may try to increase his gross income by growing intensive crops as berries and truck, or he may go into poultry. He should remember, when he does this, however, that his sidelines may be called upon to make good the losses on his extensive farming operations.

I have said that we are producing grain in competition with the western farmer. The magnitude of our job when we try to do this is shown in the comparative cost figures available for growing an acre of crop, as for instance, wheat. The 1920 cost of growing winter wheat in Kansas by horse power, over a large number of farms, in 3 counties, ranges from $17.83 to $29.62 and $24.62 per acre with a bushel cost of $1.26, $2.03 and $2.03 respectively. On the other hand the Wheat Farming Company in Kansas, one of the most

efficiently run corporation farms, reports a cost of $6.75 an acre in 1929. (*9*) The yield for the crop was 16.7 bushels per acre, giving a per bushel cost of less than 41 cents. This last figure gives us some idea as to what extremely large scale machinery can accomplish by way of cost reduction. We cannot hope to accomplish cost reductions of anything like this magnitude but it does show what is possible under ideal conditions and it also shows that a price of a dollar a bushel is not really essential to profitable wheat growing. In Pennsylvania, cost studies showed fall wheat to cost in the neighborhood of $24.00 an acre and the Central Experimental Farms report a cost of $29.06 per acre in the period from 1922 to 1926. (*10*)

The mechanization of agriculture on this continent has really never stopped but has progressed steadily ever since the advent of the binder. The economic salvation of agriculture in Ontario and eastern Canada generally rests largely, I believe, in increasing the efficiency of human labor employed and in the use of more power per worker. This, however, calls for a drastic change in the size of the family farm. Just how this change will be made remains to be seen but it is certain that the smallest units of "large scale farming equipment" can not be profitably employed without considerably increasing the crop acreages of Ontario farms. In the process of readjustment it is likely a considerable area of land will drop out of use because it is not suitable for the use of large scale machinery, consequently there may be a smaller rather than larger total output, but a greater output per worker and a higher standard of living for farmers, all of which I believe is desirable.

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# THE FORMATION OF THE HEN'S EGG *

## Part I.

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[Received for publication January 25, 1931]

Many investigators have been attracted by the diverse problems involved in the formation of birds' eggs. The domestic fowl has naturally been used extensively for the study of these problems because of its availability and, as a result, a great deal of information has been obtained concerning the formation of the hen's egg. Knowledge of the subject is, however, still far from complete, and many points remain in dispute.

The extensive literature on the subject covers a wide range of research. A review of this literature brings out the conclusion that the characteristics of the egg, such as size, depend upon both inherent and environmental factors. It is important for both the breeder and the investigator to learn what part each plays. Obviously, this can be done intelligently only when the normal process is known.

The present investigation was started at the suggestion of Dr. L. J. Cole with the object of learning more concerning the normal functioning of the hen's oviduct and determining how it could be influenced. The investigation is far from complete, but results have been obtained on some phases of the work that warrant publication. In order to present the material obtained in a concise and systematic manner, the subject has been divided into parts, each part containing a review of the literature and a description and discussion of the experiments having a bearing on the part of the subject discussed.

### I. Function of the Parts of the Oviduct

#### a. *Review of the Literature*

This part deals with the formation of the albumen, shell membrane and the shell, with its cuticle or "bloom". These are generally grouped together as tertiary membranes (Lillie, 1919) or designated the protective and nutritive membranes (Pearl and Curtis, 1912).

The albumen may be divided into three or, according to Gadow (1891), four parts. First, the chalazae or twisted cords of dense albumen continuous with a thin layer of similar consistency around the yolk. Second, an inner fluid layer which Pearl and Curtis (1912) suggest "is only a little thin albumen squeezed out of the meshes of the dense layer when the egg is broken". Third, a layer of dense albumen, which makes up the bulk of the albumen of the egg. Fourth, an outer fluid layer of albumen. The first, third and fourth layers are easily distinguished by their appearance and consistency. According to Lillie (1919) the chalazae are opaque cords of albumen twisted in opposite directions and situated at opposite sides of the yolk towards the narrow and blunt ends of the egg. The dense albumen "is composed of a

*Papers from the Department of Genetics, Agricultural Experiment Station, University of Wisconsin, Madison, Wis., No. 116. Published with the approval of the Director of the Station.
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mass of dense, closely interlaced albumen fibers, with some thin fluid albumen between the meshes of the fibrous network". This layer holds itself together in a fresh egg broken out into a plate, while the outer fluid layer flows out over the plate. It is possible, in a hard-boiled egg to strip off the albumen in concentric spiral layers from left to right from the broad to the small end of the egg.

The shell membrane consists of two layers, a thick outer layer next to the shell and a thinner inner layer next to the albumen. The outer shell membrane is over three times as thick as the inner shell membrane according to the figures given by Hays and Sumbardo (1927), who found that the mean thickness of the outer membrane, based on eggs from 11 hens, varied from .0411 mm to .0606 mm., while the corresponding thickness of the inner shell membrane varied from .0129 mm. to .0173 mm. They also report that the number of pores per square millimeter is greater in the inner than in the outer shell membrane in all cases, which agrees with the observation that this layer is made of more delicate organic fibers than the outer shell membrane.

The shell is composed of three layers, an inner or mammillary layer, an intermediate spongy layer and a surface cuticle. The intermedate spongy layer is several times as thick as the inner layer and consists of matted calcareous strands. The pores in the intermediate layer connect inwards with minute airspaces between the conical inner ends of the mammillae and outward with pores in the otherwise structureless cuticle (Lillie 1919). According to Rizzo (1899) the average number of pores counted on the surface of the shell is 1.23 per square mm. Hays and Sumbardo (1927) found that the number of pores in the equatorial region varied from 413 to 601 per sq. cm. Romanoff (1929) reports that the number of pores is greater in strong (thick) than in weak (thin) shells, the average thickness of the shell being 0.311 mm.

Before proceeding to review the formation of the egg in the oviduct, the latter may be described briefly. There are a number of papers on the histology of the oviduct of the hen and other Sauropsida. The papers having a direct bearing on the present discussion are those by Giacomini (1893), Cushny (1902), Curtis (1910), Surface (1912), Giersberg (1921, 1923), and a paper by Bradley (1928) intended to supplement the earlier report by Surface. Surface gives the length of the five parts of the oviduct as follows: funnel (ostium tubae abdominales), 2-4 cm.; albumen portion, 42 cm.; isthmus, 12 cm.; vagina, 12-13 cm. The corresponding averages given by Buckner and Martin (1929) for five laying White Leghorn hens are: funnel, 4 cm.; albumen portion, 36 cm.; isthmus, 5 cm.; uterus, 7 cm.; vagina, 10 cm.

Surface states that the wall of the oviduct has seven layers of tissue as follows: (1) a thin serous peritoneal membrane on the outside; (2) a layer of longitudinal muscle fibers, continuous with the musculature of the ventral and dorsal ligaments of the oviduct; (3) a layer of connective tissue in which larger blood vessels are found; (4) a layer of circular muscle fibers; (5) an inner layer of connective tissue; (6) except in the funnel and the vagina, there is a thick layer of convoluted tubular glands; (7) the epithelium of the duct.

Both ciliated and non-ciliated (goblet) epithelial cells occur throughout the oviduct, but the proportion and size vary in different parts of the oviduct. Giersberg and Bradley agree that the staining reactions of the gland cells in the various parts are different, probably associated with differences in function.

Considering next the formation of the hen's egg, we find that many and diverse ideas have been set forth, some of which are still in dispute. In the following account an effort will be made to indicate what is well established and what points are still unsettled.

Surface suggested, on the basis of his study of the histological structure of the oviduct, that the chalazae are formed in the funnel. Giacomini has shown, however, that other Sauropsida that lay eggs without chalazae, have better developed glands in this region. Giersberg (1921) therefore considers that the chalazae are formed in the albumen part and not in the funnel. In this connection, it is interesting that Nathusius (1893) found it difficult to demonstrate the chalazae in incomplete eggs and suggests that they are formed by a process of growth.

Pearl and Curtis (1912) demonstrated that only the thick albumen is secreted in the albumen part. The outer fluid layer is, according to their findings, added in the isthmus and uterus and is stated to pass through the shell membrane by osmosis. This layer constitutes 50 to 60 percent by weight of the albumen of the completed egg. Chomkovic (1926, 1927) has confirmed these findings, using ducks.

Analyses reported by Pearl and Curtis (1912) of laid eggs and eggs removed from the oviduct proved that the fluid outer layer of albumen does not result from the addition of water only. These analyses showed that, with both classes of eggs, while the water content of the albumen increased from 80 to 87.4 percent in the uterus, there was at the same time an increase in the total (absolute) amount of nitrogen.

The albumen of the oviduct eggs in each case, however, contained a higher percent, and in four out of thirteen cases, a larger absolute amount of nitrogen than did laid eggs from the same hens. These four exceptional cases, in which the amount of nitrogen was greater in the albumen of oviduct eggs than in the albumen of previously laid eggs, are explained by fluctuations in weight.

The egg receives its shell membrane in the isthmus by a process of discrete deposition as first pointed out by Coste (1847). Only such parts of the egg as lie within the isthmus are covered with a shell membrane. According to Giersberg (1921, 1923) the process of shell membrane formation consists of a flowing of secretion granules in little drops, cementing of these droplets into mucus fibers, removal of water and stiffening of the (keratin) fibers. Nathusius (1893, 1896) states that the shell membrane increases both in the number and size of fibers after the deposition of shell. This is contrary to the account given by Pearl and Curtis (1912) who observed eggs with apparently complete shell membranes in the caudal end of the isthmus. Some of the increases in thickness observed by Nathusius may be accounted for by variation in the thickness of the shell membrane as found

by Hays and Sumbardo. The published accounts do not exclude the possibility of some increase in the shell membrane after the egg enters the uterus, a view favored by Giersberg.

About 50 percent of the albumen is added in the uterus, the process continuing for 5 to 7 hours, by which time a considerable amount of shell has been deposited on the shell membrane. The shell is completed in the uterus and according to Giersberg (1923) the pigment and cuticle is also completed in the uterus. He thus disagrees with the suggestion made by Surface (1912) that a part of the pigment and the cuticle is contributed by the vagina.

Giersberg (1923), whose account is based mostly on birds other than the domestic fowl, states that the cuticle forms with the egg pigment. According to his account these substances are released into the lumen of the oviduct along with albumen-containing fluid, by cells in the funnel and albumen parts. This mixture of substances then passes posteriorly through the lumen of the duct into the uterus and settles as a coagulation film on the shell of the egg.

This applies only to the fleck-forming pigments, which Giersberg considers to be formed from products of decomposition of the erythrocytes after their entrance into the lumen of the duct in the funnel region. In this connection it is generally implied, even when not specifically stated, that material is added to the egg in the part of the oviduct in which that particular material is secreted.

It is of interest in connection with the foregoing account that Pearl and Surface (1908) were able to resect a piece of the albumen portion and anastomose the remaining parts of the oviduct, with little or no effect on eggs subsequently laid. Pearl and Surface (1909) also reported the results of cutting the intestine just anterior to the cloaca and anastomosing it to the oviduct just anterior to the uterus. A calcareous shell was deposited on the faeces during their passage through the shell gland. Pearl and Surface concluded that the stimulus which activates the shell-secreting glands is mechanical in nature, thus agreeing with the conclusion drawn from placing artificial "yolks" in the oviduct (Tarchanoff, 1884; Weidenfeld, 1897; Pearl and Curtis, 1914). Pearl and Surface (1909) further concluded that the formation of the shell is brought about by a strictly local reflex and is not immediately dependent upon the activity of other portions of the reproductive system. These experiments will be referred to later. Here it is sufficient to point out that they show that the oviduct can be altered without loss of function and also indicate that the immediate stimulus to secretion is mechanical..

With regard to the time required for the passage of the egg through the oviduct, Patterson (1910) states that it takes 3 hours to pass through the albumen part, 2 to 3 hours through the isthmus and remains 16 to 17 hours in the uterus before being laid. This agrees with the times given by Gadow (1891) except that the length of interval required to pass through the isthmus is reduced slightly. Pearl and Curtis (1912) fix the average time required to pass through the isthmus at 0.6 hours but otherwise agree with the estimates given by Patterson. The time that the egg remains in the

uterus is apparently variable and frequently exceeds the average given. This would partly account for the observation made by Patterson (1910) that birds laying regularly lay about one hour later each successive day until a day is skipped. That eggs are laid later each successive day has been verified by Atwood (1929), who found that the average interval between eggs varies from just over 24 hours to over 28 hours. There is a difference here of three to seven hours in the average interval between the laying of eggs on successive days and the average time calculated for the passage of the egg through the oviduct. This difference may be due to the egg remaining longer in the uterus than the average time fixed by Patterson; or it may indicate that a succeeding ovulation does not follow immediately after the laying of an egg, as maintained by Pearl and Curtis (1912).

### b. *Experimental*

Some of the experiments reported in this and the next two parts were carried out at the University of British Columbia from the middle of October (1928) until the following summer. I am indebted to my colleagues, Dr. J. G. Jervis (who operated on the birds) and to Mr. W. J. Riley, for their coöperation in the work done there. I am indebted to Dr. H. W. Hill for facilities in the Department of Bacteriology for some of the work done at the University of British Columbia. The rest of the work was done in the Departments of Genetics and Poultry Husbandry at the University of Wisconsin. It is a pleasure to acknowledge my indebtedness to Professors L. J. Cole and J. G. Halpin of these Departments, and to Professor F. L. Hishaw of the Department of Zoology, for their interest in the work and for the many helpful suggestions made by them.

*1. Stock.* The stock used at the University of British Columbia included B. P. Rocks, Rhode Island Reds, Barnevelders, White Leghorns and crossbreds. That used at the University of Wisconsin included B. P. Rocks and White Leghorns. Most of these were pullets in their first laying year but a few hens were also used.

*2. Procedure.* In order to determine the "normal" characteristics of the eggs laid by the birds used, the following information was recorded for a few eggs from each bird before she was used for experiment: (a) length; (b) four diameters at equator; (c) color; (d) photographic outline; (e) weight of egg; (f) weight of yolk; and (g) weight of fresh shell.

The measurements were made with micrometer calipers measuring to hundredths of a millimeter. The four measurements of the diameter were so spaced as to be approximately the same distance apart. One of these gave the maximum, another the minimum, diameter, thus indicating the variation in breadth for each egg.

Each egg was graded for color of shell by comparing it with egg shells numbered from 1 to 18 and ranging from white (1) to dark brown (18). On account of the great variation in the color of the eggs laid by the genetically heterogenous group of birds used for this investigation, it proved difficult to have the series so complete that the color of every egg laid could be matched exactly. The series was, however, sufficiently complete to reflect accurately enough for the present purpose the variations in the color of the eggs laid by the birds used.

The photographic outline was obtained by a method similar to that employed by Benjamin (1920). The eggs were weighed on a chemical balance to the nearest hundredth of a gram. The weight of the yolk and of the shell and shell membrane was determined by the method described by Curtis (1911).

The birds were placed in coops two to three days before they were to be operated on and were starved for about the last 36 hours. The procedures for surgical operations on fowls need not be considered in detail here, since they have been described by Nonidez (1924). The chief change made in earlier procedures was to dispense with a general anaesthetic, which agrees with common practice for such operations as caponizing males. The different operations performed are described below in connection with the discussion of the results obtained.

*3. Types of Operations.* The detailed results of some of the operations will be discussed in subsequent sections but it appears desirable to present briefly at this time a resumé of the information with regard to the operations performed. The types of operation performed, together with the number of birds operated upon in each case and the results obtained, may be summarized as follows:

I. Shortening the following parts of the oviduct:

(a) Albumen part—5 birds. None laid after the operation.

(b) Isthmus—12 birds. Two birds died after the operation. One of the remaining 10 laid.

(c) Uterus—2 birds. Neither laid after the operation.

(d) Vagina—1 bird, which did not lay after the operation.

II. Altering or narrowing the uterus by removing a longitudinal section—13 birds. Six died after the operation, while one of the remaining seven laid.

III. Uterus freed from the attached ligaments, but not operated on further—3 birds. All laid after the operation.

IV. Fistulas to the outside connecting with the part of the oviduct anterior to the posterior end of the following parts of the oviduct:

(a) Albumen portion—1 bird. No eggs obtained.

(b) Isthmus—3 birds. No eggs obtained.

(c) Uterus—9 birds. Eggs obtained from four.

V. Fistulas to the outside at different levels of the albumen portion, leading into the part of the oviduct posterior to the fistula—8 birds. No results.

VI. Miscellaneous operations.

(a) Longitudinal tear in isthmus sutured—1 bird, which subsequently laid.

(b) Uterus cauterized—2 birds. No apparent effect on eggs subsequently laid.

(c) Oviduct temporarily ligated at level of isthmus and albumen portion—3 birds. All subsequently laid.

(d) Artificial yolks inserted into albumen portion of duct—5 cases. Secretion obtained in 2 cases.

It will be seen that comparatively few of the birds (two out of the 25 that survived) whose oviducts were shortened or narrowed (I and II) laid after the operation. This was largely due to the lumen of the duct becoming occluded at the site of the operation. Various methods of performing the operation on the oviduct were tried but none of them proved entirely satisfactory. To aid in making the anastomosis and in keeping the lumen of the oviduct open, catgut wound together to form a short, thick cord was first tried. The catgut was inserted into the oviduct before completing the anastomosis. This helped in making the anastomosis but unfortunately the catgut remained as a permanent obstruction in the oviduct after becoming covered with a layer of coagulated albumen. Later gelatin capsules covered with collodion were used but proved unsatisfactory because of difficulty in keeping them in place while making the anastomosis.

Six of the eight birds that died soon after and, presumably, as a result of the operation, were found to have continued to ovulate immediately after the operation. The yolks dropped into the body cavity. This was apparently an important factor in starting the peritonitis which was the immediate cause of death. There is also reason to believe that lack of initial vigor was a contributing factor in certain cases, since some birds were only slightly affected by the operation while others recovered very slowly. In this connection it may be noted that three first-generation pullets from a cross of White Leghorn × B.P. Rock proved exceptionally hardy, as indicated by their rapid recovery after the operation.

*4. Results of Operations.* Fifty-five operations were performed and in 17 cases eggs were subsequently obtained. Those that have a bearing on the secretory function of the parts of the oviduct may now be presented.

Fistulas to the outside. Two general types of fistulas were tried, namely (1) those where the opening connected with the part of the oviduct posterior to the place where the oviduct was severed and (2) those that connected with the part of the oviduct anterior to the fistula. Such operations obviously offer a method of studying the function of different parts of the oviduct. Similar fistulas have recently been used by Reynolds (1930) and others for studying the activity of the uterus in mammals. There are, unfortunately, a number of difficulties involved in the use of this method for the present study, some of which have not been overcome. Thus, except when the fistula is at the level of the uterus, the initial operation is difficult, and it is also difficult to keep the fistula open. Furthermore, in the case of the first type of fistula, artificial "yolks" must be employed, which cannot be done until the bird is in laying condition. As a result of a combination of these and other difficulties, no results were obtained from this type of fistula. In the case of the second type of fistula, eggs were obtained from four of the nine birds with fistulas to the outside at the posterior end of the uterus. The operations on the different birds were quite similar. The one on I2398 may be described as follows:

The incision through the body wall was made about 4 cm. in front of the cloaca and was 2.5 cm. in length (figure 1). The oviduct was severed just anterior to the vagina, the vagina being left unligated. The cut end of the posterior part of the uterus was sutured, with continuous sutures, to the

Figure 1. No. I2398 showing fistula to the outside.

body wall and skin on the inferior (ventral or right) side and to the body wall only on the superior (left) side of the opening.

The bird was examined daily after the operation and the fistula kept open by inserting the index finger, coated with vaseline, into the fistula. The wound healed rapidly and the opening grew smaller until it was barely possible to insert the finger.

The operation was performed on December 18th. On January 5th an egg with a 'soft' shell was felt in the uterus just inside the opening. Twenty-four hours later the egg was about one inch away from the opening. The bird was again operated on 3 days after the presence of an egg was first noted. An incision was made around the fistula, through skin and muscles, and the adhesions broken down with the fingers, thus freeing the oviduct from the body wall. A piece 2 cm. long was then cut off the end of the oviduct. The egg was found to have moved back, through the oviduct, into the body cavity. It was removed and the oviduct sutured to the muscles, thus remaking the fistula.

The "egg," which measured approximately 45 x 39 cm., did not contain any yolk. There was a ball of very thick, apparently partly coagulated, albumen in the center surrounded by more fluid, but still dense, albumen. The shell membrane was covered with only a little shell.

The bird recovered rapidly from this second operation and at noon, February 9th, an egg was again found in the uterus. The egg was prevented from passing through to the outside by a ring of scar tissue. This was incised in several places and the cicatrix then dissected off. The bird was held up off the table and the egg removed by inserting the index finger of the right hand through the rectum and pushing the egg, while guiding it with the index finger of the left hand.

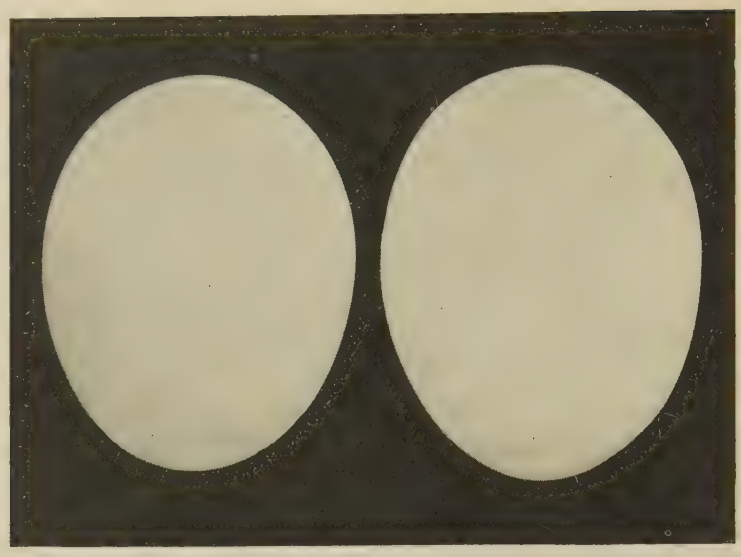

Figure 2. Eggs obtained from I2398 before (left) and after (right) the operation.

The egg thus delivered was normal in size (length and breadth) and in the total weight, as will be seen by referring to table 1. The shell weighed less than the shells of previously laid eggs from this hen, but appeared normal. The color of the shell was only a shade lighter than that of the eggs laid before the first operation. The shape was likewise the same, as nearly as could be determined (figure 2).

This same hen was found with an egg in the uterus on February 24th. There was very little shell on the membrane, so the egg was removed without operating. Eggs were again obtained on March 7th, 11th, 13th, 14th and 17th, after which the oviduct prolapsed and no further eggs were obtained. The 5 eggs obtained in March had little or no shell, but were otherwise normal.

Accurate weights of the different parts were obtained for only two of these six eggs. The technique for determining the weight of the parts of such eggs was as follows. Three beakers were first prepared. The shell membrane was then punctured with a scalpel, care being taken not to break the yolk. The albumen was drained into one of the beakers. If it appeared necessary to enlarge the opening in the shell membrane, to drain off all the albumen, a second beaker was used. The yolk and shell membrane were then pulled into a separate beaker by traction on the shell membrane. The weight of the yolk was determined by weighing the wiped shell membrane (and shell, if any) and subtracting its weight from the combined weight of the two. By this method it was possible to determine fairly accurately not only the total weight of the egg but also the weights of the diifferent parts. The weight of the yolk thus determined is in excess of the actual weight by whatever amount of albumen adhered to the yolk and the shell membrane and the weight of the albumen is correspondingly less.

Seven eggs were obtained from three other hens operated on in the same way as I2398. Five of these eggs were obtained from I287, a crossbred

TABLE 1.—*Data for eggs laid by some of the pullets that were operated on.*

| Bird's Number | No. of Eggs | Time Laid in Relation to Operation | Length | Average Diameter | Difference Between Max. & Min. Diameter | Total Weight of Egg | Weight of Yolk | | Weight of Albumen | | Weight of Shell, Etc. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mm. | mm. | mm. | gms. | gms. | % | gms. | % | gms. | % |
| 67 hens | 707 | before | 56 91 | 40.99 | .19 | 53.63 | 16.11 | 30.04 | 32.07 | 59.80 | 5.45 | 10.16 |
| I2360 | 2 | before | 60.81 | 42.53 | .24 | 63.03 | 17.43 | 27.65 | 37.90 | 60.13 | 6.91 | 10.96 |
| I2360 | 34 | after | 59.95 | 44.34 | 1.05 | 66.17 | 18.73 | 28.31 | 41.03 | 62.01 | 6.41 | 9.69 |
| I2742 | 3 | before | 58.38 | 41.44 | .19 | 58.22 | 15.66 | 26.90 | 35.86 | 61.59 | 6.70 | 11.51 |
| I2742 | 16* | after | 62.29 | 43.12 | .32 | 66.22 | 17.38 | 26.25 | 42.30 | 63.88 | 6.54 | 9.88 |
| I934 | 7* | before | 57.02 | 41.49 | .19 | 53.14 | 16.86 | 31.71 | 31.36 | 59.01 | 4.93 | 9.28 |
| I934 | 9* | after | 57.69 | 41.81 | .15 | 52.79 | 17.35 | 32.87 | 30.44 | 57.68 | 4.85 | 9.19 |
| I1698 | 6 | before | 60.00 | 42.88 | .20 | 59.51 | 17.39 | 29.22 | 36.19 | 60.81 | 5.93 | 9.96 |
| I1698 | 13* | after | 57.93 | 42.47 | .19 | 55.58 | 16.79 | 30.21 | 33.46 | 60 20 | 5.34 | 9.41 |
| I2198 | 8* | before | 58.27 | 41.22 | .20 | 54.17 | 15.62 | 28.83 | 32.32 | 59.66 | 6.23 | 11.50 |
| I2198 | 18* | after | 57.16 | 41.66 | .18 | 54.77 | 15.94 | 29.10 | 33.67 | 61.48 | 5.17 | 9.46 |
| I2398 | 2 | before | 52.14 | 42.54 | .15 | 53.63 | 14.86 | 27.71 | 32.36 | 60 34 | 6.42 | 11.97 |
| I2398 | 1 | after | 54.44 | 41.58 | .17 | 53.13 | 15.80 | 29.74 | 32.61 | 61.38 | 4.72 | 8.88 |
| 1287 | 8 | before | 55.76 | 43.85 | .14 | 59.90 | 17.81 | 29.73 | 35.64 | 59.50 | 6.45 | 10.77 |
| 812 | 12 | before | 56.74 | 39.89 | .12 | 50.29 | 15.78 | 31.38 | 29.88 | 59.42 | 4.63 | 9.21 |
| 812 | 12 | after | 55.72 | 39.07 | .33 | 47.91 | 14.32 | 29.89 | 29.05 | 60.63 | 4.54 | 9.48 |

* The weights are based on the following numbers of eggs I2742-13; I934-4. out of 7 and 4 out of 9; I1698-5; I2198-7 out of 8 and 9 out of 18.

hen of similar parentage to I2398, one was from I2592, a B.P. Rock, and one from B401, a Barnevelder hen. The weights of these eggs and of their parts, so far as they were determined are set forth in table 2. The first egg obtained from I287, after the operation, weighed less than any of the eggs normally laid by this bird. This may have been due to the fact that the egg was removed soon after it was found in the uterus. The second egg (April 4th) was unusually heavy when removed exactly 24 hours after it was first found in the uterus. The eggs removed from I2398 and I287 were left in the uterus for varying periods of time without apparently having any effect on their weight when removed. However, since the exact time that they remained in the uterus is not known, no final conclusion can be drawn with regard to this point.

TABLE 2.—*Weights of "Soft-shelled" eggs obtained from birds with fistulas to the outside.*

| Bird Number | Egg Removed | Total Weight | Weight of Yolk | Weight of Albumen | Weight of Shell and Shell Membrane |
|---|---|---|---|---|---|
| | Date | gms. | gms. | gms. | gms. |
| I2398 | March 8 | 49.00 | – – | – – | 1.79 |
| | March 11 | 48.48 | – – | – – | 1.78 |
| | March 13 | 59.34 | 20.56 | 37.08 | 1.70 |
| | March 14 | 61.88 | 18.50 | 42.18 | 1.20 |
| | March 17 | 47.37 | – – | – – | 1.45 |
| I287 | April 1 | 49.68 | 14.12 | 34.35 | 1.21 |
| | April 4 | 78.96 | 21.63 | 54.88 | 2.45 |
| | April 5 | 61.03 | 17.11 | 42.50 | 1.42 |
| | April 8 | 57.27 | 16.91 | 38.94 | 1.42 |
| | April 12 | 60.82 | 16.00 | 42.94 | 1.88 |
| I2592 | April 12 | 53.98 | – – | – – | 2.10 |
| B 401 | April 12 | 36.02 | | – – | .28 |

The egg obtained from I287 on April 12th was removed by operation (see above). A photographic outline of this egg was obtained immediately afterwards. This shows that although there was very little shell, the egg was in shape much like those laid before the operation.

The egg obtained from B401 and the first egg from I2592 (table 2) had only a little shell material, but otherwise these eggs were normal. Later, an egg with a tinted and somewhat thin shell was obtained from I2592. The color of this egg was lighter than that of normal-laid eggs from this hen and there appeared to be less cuticular material on the shell.

The results detailed in the preceding paragraphs point to certain conclusions with regard to the functioning of the oviduct and its parts. Thus, the normal-colored egg removed through the fistula from the uterus of I2398 indicates that the vagina does not contribute to the formation of the egg. This agrees with the conclusion arrived at by Giersberg (1923) and is contrary to the suggestion made by Surface (1912) that the color of the shell is completed and the cuticle laid on in the vagina.

Three of the eggs secured from I2398 and 4 of those obtained from I287 were as heavy, or heavier, than eggs laid by these hens before they were operated upon. This evidence shows that the amount secreted by the

oviduct does not depend on its position or upon its relation to the ligaments. Furthermore, the uterus of I2398 was reduced in length, without any apparent effect on the size of the egg. This agrees with the findings of Pearl and Curtis (1914). In no case observed by them was the size of the egg reduced after an operation on the oviduct.

Two of the eggs removed through fistulas were similar in shape to normally-laid eggs from the same hens. When operating on these birds it was necessary to free the uterus from the attached ligaments and to place the uterus in an abnormal, or at least unusual, position. It follows that the muscles of the uterus must be capable of exerting whatever effect they have on the shape of the egg unaided by the ligaments. It is of interest in this connection that Pearl and Curtis (1914) removed 3/4 cm. of the ventral ligament without any apparent effect on the eggs subsequently laid.

The evidence from these cases shows that the uterus can function normally when detached from its ligaments and placed in a different position. This is demonstrated by normal shell formation and deposition of color on the shell (one case), by the normal size of the eggs (seven cases) and, lastly, by the fact that the shape of the two eggs removed intact through fistulas was the same as that of normally-laid eggs from the same hens.

In connection with the secretory activity of the oviduct, it is of interest to note that albumen was secreted into the lumen of the duct at times when there was no yolk in the oviduct. This albumen hardened into rounded pellets and, in some cases, into large lumps which were difficult to remove. Only in one case, that of the first "egg" obtained from I2398, was a shell membrane and shell formed around one of these pieces of hardened albumen.

Another point of interest in this connection is the deficiency of shell on all except one of the eggs removed through fistulas. An effort was made to give all the birds complete rations but, since these hens had to be confined to cages indoors, there is a possibility that the rations did not always contain all the ingredients required. It is apparent, however, that the mere presence of an egg in the uterus does not fully account for the deposition of normal shells. Were this the case, the first egg obtained from I2398 should have had at least as much shell as the second one, which was formed after the uterus had been reduced in size.

It may also be noted that the fistulas, which contracted after the operation, became larger a few days before an egg would be observed in the uterus. This points to a hormone relationship which is able to affect the muscles of the abdominal wall. The enlargement of the fistulas is, presumably, analogous to the enlargement of the abdominal wall normally observed with the onset of egg production.

Shortening the Isthmus. Twelve birds were operated on with the object of studying the effect of removing a part of the isthmus. Since the operations on the different birds were quite similar, only the operation on the hen that laid (White Leghorn No. I2742) will be given here. The protocol for this bird reads as follows.

The incision, which was made just below the ischium on the left side, was 5 cm. long and reached to within 2 cm. of the cloaca. The isthmus was next located and a piece 2.3 cm. long was removed, which left a piece of

the isthmus over 2.5 cm. long anterior to the uterus. The cut ends were then sutured together and a gelatin capsule covered with collodion inserted in the lumen. When the cut edges were brought together the capsule slipped back into the uterus, so that the anastomosis, which was made with Lembert sutures, had to be completed without it. The opening through the body wall was closed with interrupted sutures and the skin was then similarly sutured.

The operation was performed February 20th and the first egg after the operation was laid exactly five weeks later, on March 27th. Eggs were also laid on the following days in April: 2, 4, 5, 6, 9, 10, 11, 13, 14, 15, 17, 19, 21, 22 and 24. The hen then stopped laying until May 9th, when another egg was produced. No data were collected on eggs laid after that date.

The summarized data for eggs laid by No. I2742 are presented in table 1. This pullet laid only three, comparatively large, eggs before she was operated upon. These three eggs were regular in outline and the average maximum diameter was only .19 mm. greater than the average minimum diameter. The shells were smooth and slightly tinted.

The eggs laid after the operation were distinctly longer and slightly broader than those laid before. The weight increased with the increase in size. This was due to an increase in the weight of yolk and an even greater increase proportionately in the weight of the albumen. The shell and shell membranes, which were weighed together, decreased both actually and relatively in weight in contrast to the increase in weight of the other parts. Both shell membranes were present, but they weigh so little that most of the decrease in weight must be accounted for by a diminished deposition of shell. The shells of all these eggs were white. They were all somewhat rough, with, in one spot towards the pointed end, a thickened lump surrounded by noticeably thinner shell than that covering the rest of the egg. These

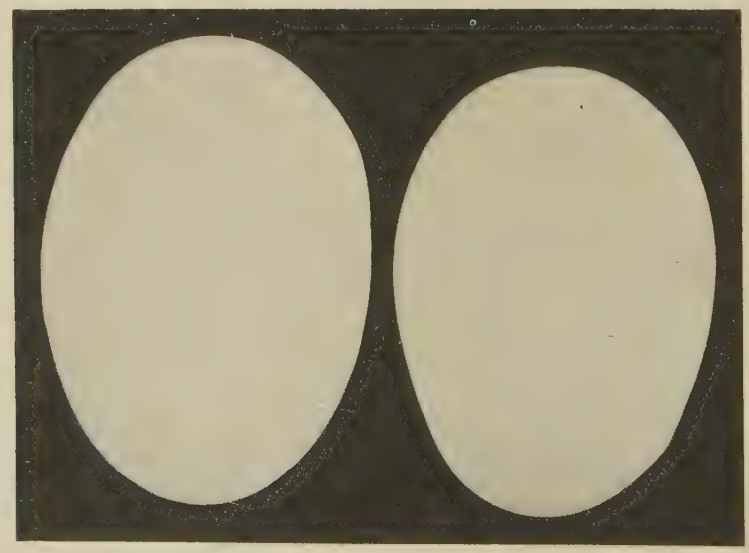

Figure 3. Eggs laid by I2742 after she was operated on showing abnormal shape of most of the eggs laid.

eggs varied considerably in shape but showed a tendency to be irregular in outline (figure 3). There was also a greater difference between the average maximum and minimum diameter.

The increased length, breadth and weight of eggs laid after the operation is to be expected, since this pullet had only laid 3 eggs. It has been repeatedly shown that the first few eggs are smaller than subsequently laid eggs. The decrease in the weight of shell appears to be significant. It has, however, been shown by Curtis (1914) and Jull (1924) that the shell is normally quite variable in weight. Some of the eggs laid after the operation had shells that were heavier than those laid before. These eggs had, proportionately, just as much shell as eggs laid before the operation. For these reasons the decrease in the weight of the shell must be considered to have no real significance so far as the operation is concerned.

The absence of pigment on the shells of eggs laid after the operation is interesting in view of the statement made by Giersberg (1921, 1923) that the fleck-forming pigment is secreted into the lumen of the oviduct in the albumen part, from whence it finds its way to the uterus and is laid on the egg. Here the removal of the anterior half of the isthmus is followed by the laying of colorless eggs. The color on this hen's eggs would be called ground color, since it was evenly distributed and not collected into flecks. The absence of the ground color from all eggs after the operation makes it appear probable that this pigment is secreted by the part of the isthmus removed. There is an alternative possibility that the secretion of the ground color, in the uterus or other parts of the oviduct, is influenced by the part removed. This is contrary to the view that each part of the oviduct functions independently of other parts. The evidence at present available favors the assumption that the pigment is secreted by the part removed.

The shape of the eggs was definitely affected by the operation. In this connection it may be noted that Pearl (1909) has stated that while the general shape of the egg may be determined before it reaches the uterus, "the particular form of each individual egg is produced in the uterus". The evidence here obtained indicates that the isthmus influences not only the general but also the particular shape of the egg. This conclusion is supported by evidence presented in the next section.

It should be noted that the shell membranes were complete although nearly half the isthmus, which is known to secrete all or most of these membranes, was removed. Apparently enough of the isthmus was left to secrete the shell membranes as normally found on bird's eggs or else, as stated by Giersberg (1923), the shell membranes are completed in the uterus. This is improbable, since it is contrary to the evidence submitted by Pearl and Curtis (1912), which shows that, in the case of the domestic fowl, the shell membranes are generally, if not always, completed in the isthmus. Furthermore, Professor Halpin informed the writer that he had removed 30 eggs with apparently complete shell membranes from the isthmus of hens suffering from egg paralysis. The observation made by Bradley that some of the glands in the uterus are lined with cells like those in the isthmus is also of interest in this connection.

*5. Eggs removed from the oviduct.* Eggs were found in the oviducts of two hens killed for data. In one hen (No. 817) the egg was partly in the isthmus, partly in the albumen portion. Only the part in the isthmus was covered with shell membrane, the membrane being thickest at the end of the egg that was farthest into the isthmus. There appeared to be little or no thin albumen. In the other case the egg was in the isthmus except for the tip of one end, which was still in the albumen part and was the only part free from shell membrane. These two eggs weighed 28.96 and 29.07 grams respectively, and thus had less than half the normal amount of albumen. These observations confirm the findings of Pearl and Curtis, noted above, that half or more of the albumen is added through the shell membrane after the egg enters the isthmus.

*6. Increase in the weight of the yolk.* The probability that the yolk increases in weight as it traverses the oviduct is pointed out by Pearl and Curtis (1912). Their data on weights of yolks in different parts of the oviduct and weights of yolks at different periods after laying (Curtis, 1911) point to the conclusion that the yolk takes up water from the albumen. This conclusion was further strengthened by the findings of Greenlee (1911) that, in eggs stored for one to three months, the proportion (percentage) of water increases in the yolks, while it decreases in the albumen. Further evidence was obtained by Bialaszewicz (1912), who found that the freezing point depression of the yolk decreased as it passed through the oviduct.

The point was tested directly by covering yolks that had been weighed in the usual way with albumen for 24 hours and then reweighing. In each of ten cases the yolk increased slightly in weight, the increase ranging from .02 to .14 grams. The odds against such a result being due to chance alone, using "Student's" method (Love, 1924), are over 10,000 to 1; hence there can be no doubt that the yolk increases in weight while in the oviduct and subsequently.

Sharp and Powell (1930) state that the literature on eggs indicates that there is an exchange of material between the yolk and albumen. Professor Halpin (unpublished data) found evidence of such an exchange. The yolks of stored eggs from hens fed cotton seed meal became quite dark and this dark color was in turn transferred to the albumen.

*7. Length of time eggs remain in the uterus.* In a number of cases where an egg was found in the uterus of birds opened for operation the time of subsequent laying of the egg was observed. These cases furnish data of interest in determining the length of time that the egg may remain in the uterus, although the results cannot be considered conclusive since the time that the egg entered the uterus is not known and the effect of the operation is also undetermined. Opening the body cavity did not apparently affect the birds adversely, so may be considered a minor factor.

The time that the eggs remained in the uterus after an operation is set forth in table 3, together with the weight of the egg and its parts and corresponding figures for previously laid eggs. In two cases the eggs, with little shell, were expelled soon after the operation. It is of interest to note that of these two, the one with the least amount of shell material (6091) had only about 58 percent of the usual amount of albumen, while the other (807)

had nearly the usual amount of albumen but only about one-fifth of the usual amount of shell. These findings agree with those of Pearl and Curtis, that much of the albumen is added after the egg enters the uterus.

TABLE 3.—*Comparison of eggs found in the uterus at time of operation and subsequently laid with the last six eggs laid before the bird was operated on.*

| Hen No. | Eggs | Time eggs remained in uterus after operation | Weight of egg | Weight of yolk | Weight of albumen | Weight of Shell |
|---|---|---|---|---|---|---|
| | No. | Hours | gms. | gms. | gms. | gms. |
| 2971 | 6 | | 46.25 | 13.31 | 27.83 | 5.12 |
| " | 1 | 18.75 | 51.37 | 14.62 | 31.93 | 4.82 |
| 3052 | 6 | | 50.91 | 14.55 | 30.72 | 5.75 |
| " | 1 | 14.0 | 46.42 | 13.25 | 29.32 | 3.85 |
| 6091 | 6 | | 60.97 | 16.24 | 38.21 | 6.52 |
| " | 1 | 1.5 | 38.40 | 15.69 | 22.04 | .67 |
| 6102 | 6 | | 49.74 | 12.48 | 31.85 | 5.40 |
| " | 1 | 10.75 | 48.73 | 12.00 | 31.74 | 4.99 |
| " | 1 | 24.50* | 47.90 | 12.86 | 30.68 | 4.36 |
| 807 | 6 | | 56.10 | 16.94 | 32.82 | 6.32 |
| " | 1 | 1.0 | 46.84 | 15.85 | 29.71 | 1.28 |
| 824 | 6 | | 44.89 | 16.54 | 24.66 | 3.69 |
| " | 1 | 23.75 | 40.08 | 15.18 | 22.15 | 2.75 |
| 827 | 6 | | 52.31 | 17.38 | 29.32 | 5.61 |
| " | 1 | 15.0 | 50.97 | 16.70 | 29.55 | 4.72 |

* Egg in albumen portion. It was laid 29.25 hours after the previous egg was laid.

With regard to the time that the egg remains in the uterus, it will be seen that the time (excluding one of the eggs from 6102) varied from 10.75 to 23.75 hours or an average for five eggs of 16.5 hours. Each of these 5 eggs had enough shell when first found in the uterus to make it so firm that there was no doubt that the shell was partly formed. The egg, therefore, actually remained longer than the indicated time in the uterus. This evidence, so far as it goes, agrees fairly well with the estimates of Patterson (1910) and Pearl and Curtis (1912) but indicates that the egg tends to stay in the uterus somewhat longer than estimated by them.

The time intervals given by Atwood (1929) agree with the assumption that the egg remains, on the average, more than 16 to 17 hours in the uterus. The time that the egg remains in the oviduct is undoubtedly one of the important variables associated with differences in rate of production. The other important variable appears to be the time at which ovulation takes place after the laying of an egg. Only in the cases specified by Pearl and Curtis (1912), that is, where a bird is laying daily, can it be assumed that ovulation takes place at about the same time as laying.

### *c. Summary*

The observations and experiments described in this part and the conclusions drawn may be summarized as follows:

1. Eggs were obtained from four hens provided with fistulas to the outside, at or near the posterior end of the uterus. Seven of these eggs were at least as large as eggs laid before the birds were operated upon.

Two of the eggs, from different hens, were similar in shape to normally laid eggs from these hens and one of the eggs had a complete, normally pigmented shell. From this it is concluded that, (a) the vagina does not take part in the formation of the hen's egg and (b) the position of the uterus and its attachment to the ligaments has little or no influence on the muscular and secretory activity of the uterus.

2. Eggs laid by a hen after nearly one-half of her isthmus had been removed were abnormal in shape, had a rough shell and the shell was devoid of color. The two shell membranes were present. Those laid before the operation were normal in shape and had slightly tinted shells. From this it is concluded that (a) half the isthmus is capable of forming normal shell membranes, (b) that the isthmus influences the shape of the egg, and (c) that it influences pigmentation of the shell.

3. In none of the cases observed did the removal of a part of the oviduct cause a reduction in the size of the eggs subsequently laid.

4. Observation on two eggs removed from the anterior part of the isthmus confirm earlier work showing that the thin outer albumen, which constitutes over half of the total albumen, is added after the egg leaves the albumen part.

5. Ten yolks left in albumen for 24 hours increased in weight in each case. From this it is concluded that the yolk increases in weight while traversing the oviduct. This supports conclusions based on earlier work.

6. Data on the time that eggs remained in the uterus of birds opened for operation indicate that the average time the egg remains in the uterus is somewhat longer than the 16 to 17 hours previously estimated.

(Parts II and III will follow in the June issue.)

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MAIZE IN SOUTH AFRICA"—A. R. Saunders. (Published by the Central News Agency Ltd. South Africa. Price £1:0:0 Net).

Maize, in recent years, has become a very important crop in those countries comprising the Union of South Africa. In the book "Maize in South Africa" by A. R. Saunders, the botanical relationships, history, cultural methods in growing, varieties, breeding and seed selection, diseases and insect pests, and uses of the crop are all thoroughly and ably discussed.

Chapter 11—"Maize Genetics, Breeding and Seed Selection"—will be of particular interest to students studying this phase of agronomy.

The whole publication should make a strong appeal to corn growers and students of agriculture in South Africa.

W. J. S.

# SEED COLOUR MARKINGS IN WHITE FLOWERED SWEET CLOVER *MELILOTUS ALBA DESR.**

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[Received for publication January 12, 1931]

The colour of well matured seed of *Melilotus alba* is golden yellow, whereas the seed of *Melilotus officinalis* is, for the most part, a dark greenish yellow. In the latter case a certain proportion of the seeds are flecked with colour which is usually purple. This flecking or spotting with purple colour has been regarded as a reliable indication that the seed should be referred to as *M. officinalis*. A statement to this effect has been made categorically by several investigators. The occurrence of colour markings on seed of *M. alba* similar to those which are found in *M. officinalis* may be, therefore, of considerable interest. It is the purpose of the writers to describe several cases where these have been found and to indicate how far they have progressed in the study of this character. The subject is of special interest to seed analysts and those associated in any way with the production of registered or certified sweet clover seed.

## Literature Review

Dahlberg (*1*) states that seed spotted with purple markings can be definitely assigned to *M. officinalis*.

Stephens and Long (*5*) published a bulletin on sweet clover seed studies which contains some interesting observations on the characteristic appearance of the seeds of *M. alba* and *M. officinalis*. As to the latter, they conclude with the following statement: "The purple flecks thus appear to be a reliable indicator of *M. officinalis* in examining samples of seed, but would not serve to determine accurately the proportion in a mixture".

Stevens (*4*) discussing the question of the admixture of yellow sweet clover seed in commercial samples of white sweet clover, uses purple spotting as a criterion of the presence of the former.

During the last few years, a committee of the Association of Official Seed Analysts of North America, under the chairmanship of Miss Anna M. Lute, carried out coöperatively a very extensive project to determine the variation of seed spotting in *M. officinalis* and the extent to which seed with colour markings occurs in *M. alba*. During the years 1925 to 1928 inclusive several thousand samples of seed were examined including bulk samples of white sweet clover and numerous individual plant samples of yellow sweet clover. A report of the committee's work was presented at the annual meeting at Des Moines in December 1929. Apparently there was nothing found to indicate the occurrence of seed with colour markings in *M. alba*.

## Colour Markings in White Blossom Sweet Clover Seed

Our attention was drawn first to the occurrence of color markings on the seeds of white blossom sweet clover by finding a single plant with heavily

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*This paper was read by Mr. W. H. Wright, Chief Seed Analyst, Dominion Seed Branch, Ottawa, at the Annual Meeting of the Association of Official Seed Analysts of North America which was held at Cleveland, Ohio, U.S.A., January 1st, 1931.

spotted seed. Some roots of *M. alba* had been transplanted into the greenhouse in the fall of 1928 and it was one of these which produced the spotted seed in the spring of 1929. Every seed was strongly marked, not with small flecks of purple, but with long heavy splashes of brick red colour. Seed of this plant, which was self-fertilized, was planted at once in the greenhouse and the seedlings later transplanted into the field. Sixty-one plants produced seed in 1930. The proportion of plants which produced spotted and non-spotted seed was 32 to 29 respectively, all of the plants having white flowers. Segregation for seed spotting was clear cut. All of the plants which had seed with colour markings were heavily spotted, whereas not even the smallest flecks could be seen with a good lens on seed from the other plants. In this case it would appear that the character of spotting was dominant over the absence of spotting. Selfed seed was secured from a majority of these plants for the purpose of studying further the inheritance of this character.

Having discovered one normal plant of *M. alba* with colour markings, an examination was made of the seed of several varieties and strains of both *M. alba* and *M. officinalis* that had been grown previously in the nursery and were known to be pure for flower colour. Reserve seed samples also of a large quantity of breeding material were examined, including a large number of inbred lines of white sweet clover.

Figure 1. Spotted seed of *Melilotus alba*. (1) Characteristic non-spotted seed of *M. alba*; (2) spotted seed of the Arctic variety of *M. alba*; (3) spotted seed of a dwarf branching strain of *M. alba*; (4) typical seed of *M. officinalis*; (5) seed from a selection of *M. alba* with heavy brick-red seed color markings.

In one half of the cases it was possible to examine seed of yellow blossom varieties which had been grown in different years and under widely different climatic conditions. There was much variability in percent of spotted seed between these determinations, and this appeared in general to be due

to degree of maturity. The counts reported for S.P.I. numbers were made on the seed samples as originally received These samples appeared to be quite mature. From three to ten counts of 100 seeds each were made in varieties of the yellow flowered species, whereas several thousand seeds were examined in varieties of *M. alba.* Table 1 gives a list of the varieties which were examined and the percentage of spotted seed in each.

TABLE 1.—*Percentage of spotted seed in varieties of melilotus alba and yellow blossom species of melilotus which have been proven to be pure by growing tests.**

| White Blossom (*M. alba*) | | | Yellow Blossom (*M. spp*) | | |
|---|---|---|---|---|---|
| Variety | Strain number | Percentage of Spotted Seed. | Variety | Strain Number | Percentage of Spotted Seed. |
| Arctic | Sask. 439 | 1 | M. officinalis | Sask. 442 | 31 |
| Grundy County | " 1317 | 0 | Daghestan | " 447 | 34 |
| Early Leafy | " 1351 | 0 | Zouave | " 788 | 30 |
| Little Wonder | " 1352 | 0 | Albotrea | " 448 | 34 |
| Dentatis | " 435 | 0 | Alberta | " — | 10 |
| Hubam | " 1305 | 0 | Early Prolific | " 1315 | 13 |
| Crystal Dwarf | S.P.I. 05326 | 0 | Redfield Yellow | S.P.I. 40937 | 19 |
| Stones Early | " 12067 | 0 | Suaveolens | " 27291 | 61 |
| Taylor's Acid Soil | " 03917 | 0 | M. Officinalis | " 10036 | 18 |
| Chantlands | " 05647 | 0 | M. spp. | " 27474 | 87 |
| M. alba | " 05344 | 0 | " " | " 27475 | 49 |
| M. alba | " 52916 | 0 | " " | " 27476 | 40 |
| M. alba | " 27465 | 0 | " " | " 27477 | 50 |
| M. alba | " 28366 | 0 | " " | " 61320 | 17 |
| M. alba | U.S.D.A. 1701 | 0 | " " | " 61300 | 19 |
| M. alba | " 2468 | 0 | | | |
| Alpha | 1 | 0 | | | |
| Dwarf-Branching | 2 | 0 | | | |
| " " | 3 | 0 | | | |
| " " | 4 | 0 | | | |
| " " | 5 | 100 | | | |
| " " | 6 | 0 | | | |
| Brandon Dwarf | – | 0 | | | |

* Thanks are due to Mr. Lorne Burke, Supervising Seed Analyst, Dominion Seed Branch, Saskatoon, for his assistance in carefully checking all determinations with *M. alba.*

Seed inspection of the various varieties, strains and inbred lines of *M. alba* was rewarded by the discoverey that a variety of sweet clover known as "Arctic" contained about one percent of colour flecked seed. These markings were not easily apparent to the naked eye but clearly visible under a lens. Plants from these spotted seeds are now in the field and will produce seed in 1931.

The finding of spotted seed in Arctic sweet clover was somewhat of a surprise, since we had been growing elite seed of this variety for many years. An admixture of yellow sweet clover would certainly have been suspected, were it not known that the seed stocks were pure. Flecked seed was found also in a sample from our mass selected seed plot which contained only spaced plants of the Arctic variety. These had been carefully rogued for off-type plants and no yellow sweet clover was present.

Spotted seed was found also in the variety Grundy County. About I per 1000 seeds was obtained or one-tenth of one percent. In this case it is possible that the spotted seed may have been due to an admixture of *M. officinalis,* although this is rather improbable as no yellow flowered plants were observed in the growing test. Grundy County, like Arctic, belongs to the group of mid-tall, early maturing varieties of white flowered biennial sweet clover.

Finally, an examination was made of a number of dwarf strains of *M. alba,* one of which has recently been named "Alpha". These represent a new type of white blossom sweet clover that is characterized by comparatively numerous and short fine leafy branching stems. The origin, characteristics and agricultural value of several strains of the Alpha-type sweet clover have been published in a recent bulletin (*2*).

One of these strains of dwarf white blossom sweet clover proved to have seeds which were strongly flecked with purple. This was strain No. 5. None of the others showed the least indication of colour markings. In a bulk lot of strain No. 5 every seed was heavily spotted. (See table 1).

Three years before it was found that strain No. 5 had purple spotted seed, crosses had been made between plants of an inbred line of this strain and common white blossom sweet clover. Seed from four $F_1$ plants were obtained and all of these had purple markings. This constituted further evidence that seed spotting is a dominant character. The $F_2$ families from these crosses are in the field at the present time and will mature seed in 1931. With the hybrid material from these crosses and the selfed seed mentioned above, it is hoped that a good beginning may be made in a study of the inheritance of this character.

The senior author (*3*) has recently completed an inheritance study of flower colour in a cross between *M. alba* and *M. officinalis*. The seed character of the parents is not known but no indication of spotting has been found in seed from the $F_1$ plant nor from plants in $F_2$. An examination also of fifty-four $F_3$ families failed to show any sign of seed spotting. This, of course, was not surprising, since it is fairly well established that many plants of *M. officinalis* show no seed spotting whatever. Out of 58 individual plants of yellow sweet clover examined recently, only 18 had spotted seed. This is in keeping with what has been found by other workers. In every case where spotting was observed all of the seed showed this character, although some were more heavily flecked than others on the same plant.

## Summary and Conclusion

1. Purple flecking or spotting of sweet clover seed has been regarded as a reliable indication that such seed belongs to yellow sweet clover. *M. officinalis.*

2. Sweet clover seed with colour markings, indistinguishable from those of *M. officinalis,* has been found in the white flowered species *M. alba.*

3. The Arctic variety of white flowered sweet clover had about one percent spotted seeds, and a strain of dwarf white blossom sweet clover had 100 percent of spotted seeds.

4. The character of "colour markings" on sweet clover seed appeared to be dominant over the absence of "colour markings".

5. Colour markings on sweet clover seed cannot be regarded as conclusive evidence that the seed belongs to *M. officinalis*.

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## BOOK REVIEW

"The Plant Quarantine and Control Administration" by Gustavus A. Weber, Service Monograph of the United States Government, No. 59, pages I-X, 1-198. Published by The Brookings Institute, Washington, D.C., 1930. Price $1.50.

This volume is one of a series prepared and published by The Brookings Institute on the history, organization and activities of the various Departments of the United States Government. "These monographs are all prepared according to a uniform plan. They give: first, the history of the establishment and development of the service; second, its functions, described not in general terms, but by detailing its specific activities; third, its organization for the handling of these activities; fourth, the character of its plant; fifth, a compilation of, or reference to, the laws and regulations governing its operations; sixth, financial statements showing its appropriations, expenditures and other data for a period of years; and finally a full bibliography of the sources of information, official and private, bearing on the service and its operations".

In the section entitled "History", a review is given of the insect and pest legislation enacted by Congress including the Plant Quarantine Act of 1912. the reasons for the establishment of Quarantine 37, and a summary of the legislation affecting such projects as the European corn borer, Mediterranean fruit fly, Japanese beetle, white pine blister and black stem rust. Under "Activities" a summary of the various projects is given, and the section dealing with "Organization" lists the positions with salaries under the various projects. Included in the "Appendix" are the laws administered by the organization, financial statement, publications, and bibliography, etc.

This work is of inestimable value to all those who are in any way interested in insect or plant disease legislation. It should prove to be most useful not only as a current reference as showing the activities that are being carried out today, but also as a general reference in that it records the steps that have been taken to develop the Plant Quarantine and Control Administration to its present size and state of efficiency.

L. S. McL.

# SULPHUR OXIDATION IN ALBERTA SOILS AND RELATED EXPERIMENTS

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[Received for publication January 12, 1931]

The soil reaction is one of the important factors governing growth and activity of soil microörganisms and higher plants, and it is therefore important to study methods of regulating or maintaining the neutrality, acidity, or alkalinity of the soil. Crop growth can frequently be increased by reducing soil acidity and the cheapest and most satisfactory method of reducing soil acidity usually is to apply lime to the soil. Sometimes, however, it is desirable to reduce the alkalinity or increase the acidity of a soil, and this can probably be done more cheaply and satisfactorily by applying elementary sulphur than by any other method.

When the experiments reported by O. R. Younge (*16*) showed that sulphur oxidation proceeds rapidly in three widely separated classes of Alberta soil, without artificial inoculation with sulphur oxidizing bacteria, it was considered desirable to investigate possible applications of this information. A number of practical applications have been suggested at different times by various investigators. Several of these applications are briefly mentioned in the following paragraph, and other possible applications will be considered later.

Certain American soils, particularly in the north-western States of Oregon and Washington, are deficient in sulphur, and produce larger yields of alfalfa and other crops when sulphur is applied (*9*). In this connection it should be stated that Alberta soils are, apparently, not deficient in sulphur (*15*). It has been shown by Lipman and others (*6, 8, 13*) that the biological oxidation of sulphur in soils or composts will increase the availability of phosphates and other minerals. The use of sulphur in the reclamation of black alkali soils has been a subject of considerable experimentation (*3, 4, 5, 10*), and it has been shown that the sulphuric acid produced neutralizes the alkaline carbonate salts and aids percolation and leaching by flocculating the colloidal particles.

A correlation between hydrogen-ion concentration of soils and occurrence of common potato scab has been observed. Gillespie and Hurst (*2*) reported that examination of a large number of soils from northern Maine showed an excellent correlation between hydrogen-ion concentration and occurrence of common scab. Soils having a pH value as low as 5.2 rarely produced scabby potatoes. Sanford (*11*) suggests that severe scab may be expected in soils ranging from a strongly alkaline reaction to at least pH 5.4, owing to the higher pH value of the tuber and a strong tendency of the pathogene to make its habitat, the scab pustule, alkaline. The limiting acid reaction for germination of the spores of a strain of the pathogene, *A. scabies*, he found to be about pH 5.3. Sanford (*12*) also observed that in certain seasons abundant scab may develop in very dry soils, while soils sufficiently moist produce almost clean tubers. The control of common scab of potatoes by applying

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sulphur to the soil and thereby increasing the acidity of the soil in which the potatoes are growing has been attempted by various workers. The use of sulphur for this purpose, however, has not given uniformly satisfactory results. Successful control has been reported in certain cases, as, for example, Martin at New Jersey (*7*) reported substantial gains in the number of clean tubers with different applications of sulphur.

It has been suggested that injurious insects and weeds may, in some cases, be controlled by making the soil sufficiently acid with sulphur, and this is therefore another possible use for elementary sulphur .

An experiment was started in 1928 to determine, if possible, if control of common scab of potatoes in Alberta soils by sulphur treatments would be feasible. Three widely separated classes of Alberta soil, representing three major soil belts, were used in this experiment. For this experiment the brown soil belt sample was obtained at Brooks, Alberta, the black belt sample at Edmonton, and the wooded belt sample at Breton, Alberta.

Nine boxes were filled with each soil and a "set" of scabby potatoes of the Irish Cobbler variety was planted in each. Three boxes of each soil were used as checks, three were treated with sulphur at the rate of one ton per acre (i.e. per 2,000,000 lbs. of soil), and three at the rate of three tons per acre. The sulphur was thoroughly mixed with the soils, and the soils were kept moist by watering periodically throughout the summer.

The results obtained in 1928 were rather incomplete, but some control of potato scab was obtained in the sulphur treated soil. The experiment was repeated in 1929 and more complete information was obtanied. The 1929 results are given in tables 1 and 2.

The results obtained in the 1929 experiments with all three soils, as shown in table 1 and figures 1, 2, and 3, indicate that it may be possible to control common scab of potatoes in Alberta by treating the soils with sulphur. The three ton application was sufficient to prevent, or practically prevent, development of potato scab in all three soils. The one ton application reduced scabbiness somewhat, but was not sufficient to effectively control the disease in these soils. Possibly a two ton application would have been sufficient, but this was not tried. It is evident that three tons of sulphur applied to Brooks soil in 1928 made the soil too acid for satisfactory potato crop growth in 1929, although the 1928 yield was about the same as that of the untreated checks. It seems apparent from these experiments that when the sulphur is applied at the time of planting the potatoes, the full effect of its oxidation is not obtained in the first season. The aim should evidently be to apply sufficient sulphur to prevent potato scab development, without adding enough to reduce the potato crop yield.

The soil reactions were determined on six different occasions throughout the 1929 growing season, and the pH values obtained are given in table 2. These were determined with a potentiometer and quinhydrone electrode, using soil solutions prepared by shaking up composite samples of soil in the proportions of one part of soil to two parts of carbon dioxide-free water.

It will be observed in each case that the untreated soils are least acid, and the soils to which sulphur was added at the rate of three tons per acre are most acid. In the case of the Brooks soil it is possible to compare the

TABLE 1.—*Effect of sulphur treatments of soils in box cultures on scabbiness and yields of potatoes, 1929.*

BROOKS SOIL

| Check, 1928-29 S not applied | 1 ton S, 1928-29 S appl. spring, 1928 | 3 tons S, 1928-29 S. appl. spring, 1928 |
|---|---|---|
| 289 grams | 283 grams | 52 grams |
| 308 " | 293 " | 58 " |
| 242 " | 309 " | 14 " |

Note: Check, 1928-29: Extremely scabby
1 ton S " Moderately scabby
3 tons S " No scab, but small and rough skinned.
(See Figure 1.)

EDMONTON SOIL

| Check, 1929 S not applied | 1 ton S, 1929 S appl. spring, 1929 | 3 tons S, 1929 S appl. spring, 1929 |
|---|---|---|
| 549 grams | 395 grams | 423 grams |
| 458 " | 426 " | 363 " |
| 465 " | 370 " | 386 " |

Note: Check, 1929: Moderately scabby.
1 ton S " " "
3 tons S " Quite free from scab apparently.
(See Figure 2).

BRETON SOIL

| Check, 1929 S not applied | 1 ton S, 1929 S appl. spring, 1929 | 3 tons S, 1929 S appl. spring, 1929 |
|---|---|---|
| 324 grams | 261 grams | 163 grams |
| 334 " | 261 " | 235 " |
| 288 " | 293 " | 223 " |

Note: Check, 1929: Moderately scabby
1 ton S " Less scabby than check
3 tons S " Practically free from scab.
(See figure 3).

TABLE 2.—*Effect of sulphur treatments of soils in box cultures on* pH *values of soils. 1929*

| | May 28 pH | June 25 pH | July 10 pH | Aug. 6 pH | Aug. 27 pH | Sept. 17 pH |
|---|---|---|---|---|---|---|
| Brooks soil, 3 T.S., 1929 | 6.7 | 5.5 | 3.9 | 2.9 | 4.5 | 3.5 |
| " " Check, 1928-29 | 7.0 | 6.6 | 5.6 | 5.8 | 6.4 | 5.9 |
| " " 1 T.S., 1928-29 | 6.1 | 5.7 | 4.4 | 5.2 | 5.3 | 5.2 |
| " " 3 T.S., 1928-29 | 5.3 | 4.0 | 3.0 | 3.1 | 3.7 | 3.3 |
| Edm. soil, Check, 1929 | 6.5 | 6.1 | 5.1 | 4.9 | 5.0 | 5.2 |
| " " 1 T.S., 1929 | 6.5 | 5.8 | 4.7 | 4.9 | 5.0 | 5.2 |
| " " 3 T.S., 1929 | 6.5 | 5.3 | 4.3 | 4.7 | 5.0 | 4.5 |
| Breton soil, Check, 1929 | 6.7 | 6.4 | 5.4 | 5.1 | 6.1 | 5.2 |
| " " 1 T.S., 1929 | 6.7 | 6.0 | 5.1 | 5.3 | 4.6 | 5.1 |
| " " 3 T.S., 1929 | 6.7 | 5.3 | 3.8 | 4.0 | 4.0 | 3.6 |

heavy treatment, applied at planting time, with a similar treatment applied a year earlier. It will be observed that when the heavy application was made in 1928 the soil became very acid early in the following season, and, as previously pointed out, the potato crop growth was greatly retarded. It should also be observed that the heavy application of sulphur did not increase the acidity of the Edmonton soil as much as it increased the acidity of the Brooks and Breton soils, and this is in accord with the previous experiments in which it was shown that a similar Beaverlodge soil has a high buffer effect. The pH values fluctuated considerably throughout the season, even in the cases of the untreated or check soils. Such fluctuations are apparently brought about by seasonal changes in environmental conditions. Fairly large fluctuations have been observed by other workers with other soils, and it has been shown, for example, that drying a soil may alter its pH value considerably. It seems very doubtful, therefore, if one should state that any given soil has a perfectly definite pH value.

The earlier experiments with sulphur for the control of common scab of potatoes were apparently nearly all conducted with applications of less than one ton per acre. A one-ton application had little effect upon the pH value of the Edmonton soil, and was not sufficient to prevent potato scab development in any of the soils. This may account for the lack of control and irregularity of results obtained in some of these earlier experiments.

In May, 1930, the boxes of soil used in 1929 were watered and again planted to scabby Irish Cobbler potatoes without further addition of sulphur. The reaction or pH value of each soil was very similar to that of the previous season. With the 3 ton application of sulphur the reactions were about pH 3.6 in the Breton and Brooks soils and about pH 4.8 in the Edmonton soil. With the 1 ton application the reactions were about pH 4.6 in the Breton and Brooks soils and about pH 5.6 in the Edmonton soil. The effect upon potato scab in Brooks and Breton soils was similar to that obtained in 1929, but with Edmonton soil the untreated as well as the treated cultures produced potatoes free from scab. In the case of the Breton soil the potatoes from untreated soil were moderately scabby, from soil treated at the rate of one ton per acre, slightly scabby, and from soil treated at the rate of three tons per acre the potatoes were free from scab. In the case of the Brooks soil the potatoes from untreated soil were very scabby, from soil treated at the rate of one ton per acre, moderately scabby, and from soil treated at the rate of three tons per acre the potatoes were free from scab.

In addition to the box culture experiments, field tests on a small scale were conducted in 1930 on Edmonton and Breton soils. Sulphur was applied to the treated plots immediately before planting the potatoes. It was spread uniformly and hoed in, and scabby Irish Cobbler potatoes were planted. Each plot consisted of one square rod, and as this experiment was regarded as a preliminary field trial the treatments were not replicated. The Breton plots were treated and planted May 27th and harvested September 19th, whereas the Edmonton plots were treated and planted May 12th and harvested September 29th. The sulphur treatments, pH values of soils, relative scabbiness of potatoes, and yields in grams are given in table 3.

The Breton soil was relatively infertile and the yields are low as compared to Edmonton soil yields. The pH values of the soils were determined only twice during the summer, and, since pH values fluctuate considerably, the maximum acidities may have been greater than indicated. Sulphur was applied at the rates of one and two tons per acre to the Breton plots and at the rates of two and three tons per acre to the Edmonon plots, and, apparently, the treated Breton soil became more acid than the treated Edmonton soil. The sulphur treatments produced a marked reduction in potato scab in the

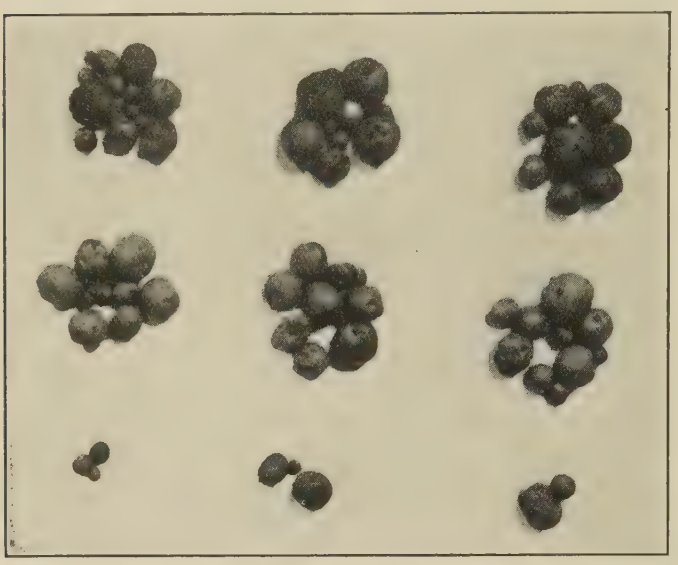

Figure 1. Brooks Soil.

Check, 1928-29. Very scabby.

1 ton S, 1928-29. Moderately scabby.

3 tons S, 1928-29. No scab, but small and rough skinned.

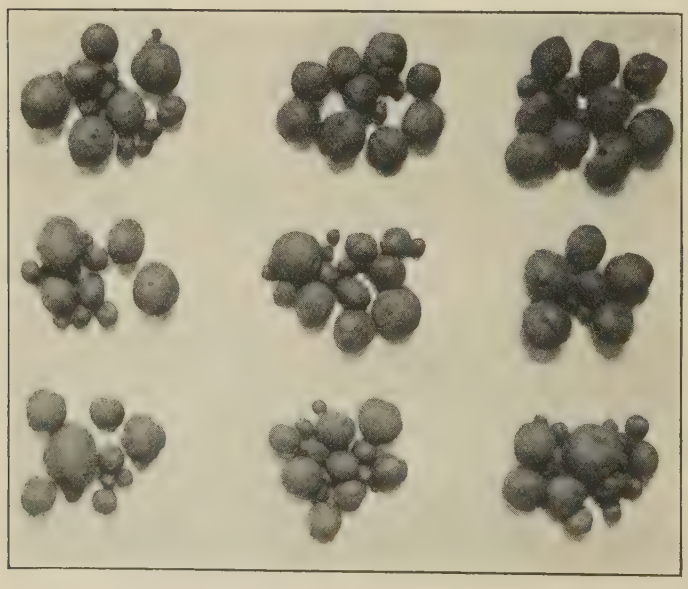

Figure 2. Edmonton Soil.

Check, 1929. Moderately scabby.

1 ton S, 1929. Moderately scabby.

3 tons S. Free from scab.

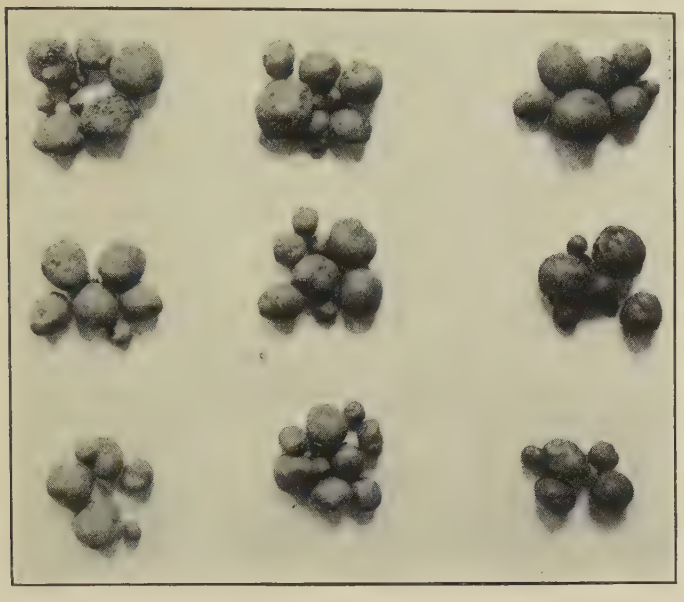

Figure 3. Breton Soil.

Check, 1929. Moderately scabby.

1 ton S, 1929. Less scabby than check.

3 tons S, 1929. Practically free from scab.

Breton soil, as shown in table 3. The sulphur treatments also reduced potato scab in the Edmonton black soil, as shown in table 3, but in this case the experiment was not considered as satisfactory, for the plots were placed in a corner of the field where the soil was not uniform. The fact that the three-ton application did not produce cleaner potatoes than the two-ton application may have been due to a difference in soil, as it was observed that the surface layer of black loam above the clay subsurface soil was distinctly shallower in the three-ton plot than in the two-ton plot, and the soil did not become quite as acid in the former plot as in the latter.

It will be interesting to see if the acidities of the sulphur treated field soils are maintained in future seasons without further addition of sulphur, as previously observed in the box culture experiments.

It is realized that the cost of applying, for example, two tons of sulphur per acre, would not be justified by the production of one scab-free crop of potatoes, but it might be practicable to retain this treated land for potato growing, and maintain the required acidity by occasionally applying relatively small quantities of sulphur. It would probably be unwise, for various reasons, to grow potatoes every year on the same land, but some fairly acid-resistant crop might be grown in between crops of potatoes. If it were found desirable, at any time, to change back to ordinary crops, this could be done by applying lime or marl to neutralize the soil acidity.

Potato scab control by this method might prove more important in the less acid or slightly alkaline soils of the prairie provinces, and interior of British Columbia, than in the more humid areas of the East. In eastern Canada and eastern United States the soils are commonly acid in reaction, and, insofar as acidity is a controlling factor, potatoes grown on these soils should normally be less scabby than potatoes grown on most of our western soils.

TABLE 3.—*Effect of sulphur treatments of field plot soils on scabbiness of potatoes and* pH *values of soils. 1930.*

| Treatment | Very Scabby | | Moderately Scabby | | Slightly Scabby | | Free from Scab | | Total | pH | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight in grams | Percent of total wt. | Weight in grams | Percent of total wt. | Weight in grams | Percent of total wt. | Weight in grams | Percent of total wt. | Weight in grams | | |
| | | | | | BRETON PLOTS | | | | | July 31 | Sept. 23 |
| Check | 6,822 g | 42% | 5,937 g | 36% | 3,315 g | 20% | 257 g | 2% | 16,331 g | 5.7 | 6.5 |
| 2 tons S | 48 g | 0% | 2,075 g | 13% | 9,426 g | 60% | 4,314 g | 27% | 15,863 g | 4.6 | 3.9 |
| 1 ton S | 1,255 g | 7% | 3,351 g | 19% | 8,900 g | 50% | 4,220 g | 24% | 17,726 g | 4.9 | — |
| | | | | | EDMONTON PLOTS | | | | | July 29 | Sept. 12 |
| Check (double size) | 21,959 g | | 25,944 g | | 66,955 g | | 9,914 g | | 124,772 g | | |
| Half of check | 10,979 g | 18% | 12,972 g | 21% | 33,478 g | 53% | 4,957 g | 8% | 62,386 g | 6.1 | 6.1 |
| 3 tons S | 1,576 g | 3% | 4,849 g | 9% | 38,402 g | 70% | 10,259 g | 18% | 55,086 g | 4.7 | 4.8 |
| 2 tons S | 128 g | 0% | 3,377 g | 5% | 49,749 g | 79% | 10,255 g | 16% | 63,509 g | 4.7 | 4.6 |

Another experiment was conducted with the object of determining the effect of sulphur oxidation in soils upon the growth of dandelions in lawns. For this experiment the following three soils were used: Edmonton black loam, Breton white or wooded loam, and Winterburn fine sandy loam. Sulphur was mixed with these soils in the proportions stated in table 4, and the soils were placed in 32 one-gallon crocks, 2 crocks being used for each treatment or check. Four dandelion seedlings were planted in each crock. Creeping bent grass was also planted in 24 of the crocks, or a series of 8 crocks of each soil, and a lawn grass seed mixture was planted in another 8 crock series of the Winterburn soil, numbered 25 to 32 (inclusive). Drainage was provided for and the crocks were watered frequently.

The experiment was started in November, 1929, and continued until June, 1930. The tabulated notes in table 4 were taken in June, or near the end of the experiment.

TABLE 4.—*Effects of sulphur oxidation on growth of grasses and dandelions.*

| Crocks | Soil | Sulphur Application Rate per acre | Grass | Dandelions |
|---|---|---|---|---|
| 1,2 | Edmonton black loam | 0 tons | Strong growth | Strong growth |
| 3,4 | " " " | 3 " | " " | " " |
| 5, 6 | " " " | 5 " | " " | Weak growth |
| 7, 8 | " " " | 7 " | Nearly dead | All dead |
| 9, 10 | Breton wooded loam | 0 " | Strong growth | Strong growth |
| 11, 12 | " " " | 2 " | " " | " " |
| 13, 14 | " " " | 3 " | Fair growth | All dead |
| 15, 16 | " " " | 5 " | All dead | " " |
| 17, 18 | Winterburn fine sandy loam | 0 " | Strong growth | Strong growth |
| 19, 20 | " " " " | 2 " | " " | " " |
| 21, 22 | " " " " | 3 " | " " | " " |
| 23, 24 | " " " " | 5 " | Weak growth | All dead |
| 25, 26 | " " " " | 0 " | Strong growth | Strong growth |
| 27, 28 | " " " " | 2 " | " " | " " |
| 29, 30 | " " " " | 3 " | " " | Med. growth |
| 31, 32 | " " " " | 5 " | Weak growth | All dead |

The experiment indicates that lawn grass would often be seriously injured by the large amount of sulphur or acidity required to kill the dandelions. On ordinary lawns, where the moisture content of the soil would probably vary more, and where the acidity could be maintained for a longer period, somewhat different results might be obtained. It has been stated that lawns which have been fertilized with ammonium sulphate for a number of years are freer from dandelions than similar lawns treated with other nitrogen fertilizers, and since ammonium sulphate leaves an acid residue of sulphuric acid or sulphate, it was considered that the same result might possibly be obtained more rapidly by the use of sulphur.

The pH values of the soils were determined at three different times during the course of the experiment. The numbers of bacteria and fungi were also determined by the plate count method, in all soils twice, and three times in some of the soils. The results of these determinations are given in

TABLE 5.—*Effects of sulphur oxidation on* pH *values and numbers of microorganisms in soils.*

| Crocks Fungi | Soil | Tons S per acre | pH Dec. 11 | pH Jan. 8 | pH Mar. 12 | Millions per g. moist soil | | Millions per g. dry soil | | Millions per g. dry soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Bacteria Feb. 18 | Fungi Feb. 18 | Bacteria June 2 | Fungi June 2 | Bacteria June 20 | Fungi June 20 |
| 1, 2 | Black loam (Edmonton) | 0 | 5.6 | 5.5 | 5.6 | 9.13 | .050 | 7.68 | .081 | 10.2 | .131 |
| 3, 4 | " " " | 3 | 4.6 | 4.3 | 4.2 | | | 5.73 | .073 | 7.48 | .081 |
| 5, 6 | " " " | 5 | 4.0 | 3.6 | 3.5 | | | 2.34 | .069 | 3.71 | .080 |
| 7, 8 | " " " | 7 | 4.0 | 3.3 | 3.1 | 4.46 | .051 | 5.65 | .081 | 2.46 | .066 |
| 9, 10 | Gray loam (Breton) | 0 | 7.1 | 7.3 | 6.8 | 8.36 | .035 | 6.42 | .039 | 5.64 | .053 |
| 11, 12 | " " " | 2 | 4.3 | 3.7 | 3.9 | | | 5.35 | .036 | 3.96 | .039 |
| 13, 14 | " " " | 3 | 3.9 | 3.4 | 3.4 | | | 4.13 | .062 | 3.94 | .047 |
| 15, 16 | " " " | 5 | 3.8 | 3.1 | 3.1 | 3.45 | .022 | 5.66 | .041 | 1.79 | .051 |
| 17, 18 | Fine sandy loam (Winterburn) | 0 | 6.5 | 6.3 | 6.1 | 10.16 | | 9.36 | .031 | 7.39 | .066 |
| 19, 20 | " " " " | 2 | 4.8 | 4.2 | 4.5 | | | 7.34 | .051 | 5.32 | .040 |
| 21, 22 | " " " " | 3 | 4.2 | 3.8 | 3.9 | | | 6.11 | .047 | 4.40 | .067 |
| 23, 24 | " " " " | 5 | 3.2 | 3.1 | 3.1 | 3.83 | | 1.42 | — | 2.43 | .049 |
| 25, 26 | " " " " | 0 | 6.5 | 6.2 | 6.6 | | | 6.81 | .024 | 4.37 | .051 |
| 27, 28 | " " " " | 2 | 4.2 | 4.1 | 4.4 | | | 8.38 | .029 | — | .101 |
| 29, 30 | " " " " | 3 | 3.9 | 3.7 | 3.6 | | | 3.92 | .025 | 4.33 | .068 |
| 31, 32 | " " " " | 5 | 3.2 | 3.1 | 3.1 | | | 1.86 | — | 1.76 | .029 |

table 5. There are some irregularities in the counts of microörganisms, but it is evident that the numbers of bacteria were generally reduced by the increase in acidity. A beef peptone agar medium recommended by Fred (*1*) was used for the bacterial count plates. The numbers of fungi, according to Waksman's acid agar plate count method (*14*), were not correspondingly reduced.

## Summary

Experiments were started in 1928 to determine whether control of common scab of potatoes in Alberta soils by sulphur treatments would be possible or feasible. Three widely separated classes of Alberta soil were used in the experiment: Edmonton black loam, Brooks brown loam, and Breton gray or wooded loam.

Some control of potato scab was obtained in boxes of sulphur treated soil in 1928. The experiment was repeated and the results obtained with all three soils in 1929 and 1930 indicate that it is possible to control common scab by treating the soils with sulphur. A three ton per acre application was sufficient to prevent or practically prevent development of potato scab in all three soils. This application apparently reduced yields slightly in two of the soils and seriously in one soil. A one ton application had little effect on yields and reduced scabbiness somewhat, but was not sufficient to effectively control the disease in these soils.

The soil reactions were determined on six occasions throughout the 1929 growing season. The untreated soils were least acid and the soils to which sulphur was added at the rate of three tons per acre were most acid, but the heavy applications of sulphur did not increase the acidity of the Edmonton soil as much as it increased the acidity of the Brooks and Breton soils.

The pH values fluctuated considerably throughout the season. Fairly large fluctuations have been observed by other workers, and it seems doubtful, therefore, if one should state that any given soil has a perfectly definite pH value.

In addition to the box culture experiments, field tests on a small scale were conducted in 1930 on Edmonton and Breton soils. The sulphur treatments reduced potato scab to a marked degree in the Breton soil, and to a lesser degree in the Edmonton soil, but in the latter case the experiment was not considered very satisfactory, for the plots were placed in a part of the field where the soil proved to be lacking in uniformity.

The earlier experiments with sulphur for the control of common scab of potatoes were apparently nearly all conducted with applications of less than one ton per acre. A one ton application had little effect upon the pH value of the Edmonton soil, and was not sufficient to prevent potato scab development in any of the soils.

The results presented in this paper indicate that common scab of potatoes cannot be satisfactorily controlled by the sulphur method in Alberta soils without applying relatively large quantities of sulphur, and the cost of applying, for example, two tons of sulphur per acre, would not be justified by the production of one scab-free crop of potatoes. It might be practicable,

however, to retain sulphur treated land for potato growing, and maintain the required acidity by occasionally applying relatively small quantities of sulphur. Further experimental work upon this question is desirable.

Another experiment was conducted with the object of determining the effect of sulphur oxidation in soils upon the growth of dandelions in lawns. Pot cultures of three soils were used. The experiment indicates that lawn grass would often be seriously injured by the large amount of sulphur or acidity required to kill the dandelions.

The numbers of bacteria and fungi in these soils were determined by plate count methods, and soil pH values were determined also. The numbers of bacteria were generally reduced by increase in acidity, but the numbers of fungi were not correspondingly reduced.

## Acknowledgments

The writer wishes to acknowledge the assistance given at various times by several members of the Soils Laboratory Staff, including Messrs. R. H. Bedford, C. Obee, E. Keen, and A. D. Paul.

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# NOTES ON AGRICULTURAL EXTENSION *

## I. Qualifications of Extension Workers

W. V. Longley †

The qualifications of an extension worker cannot be better stated than in the study by H. C. Ramsower, director of extension in Ohio, presented at the annual conference of extension workers for Minnesota in December 1926. The address of Mr. Ramsower was based on a survey of the county agent personnel in 34 states. Twenty qualities of leadership were enumerated and 133 agents selected from a total of 1,400 agents were rated by 143 persons. Seven qualities ranked close together above all others, namely: integrity, perseverance, faith, ability to plan, vision, initiative, and courage. Mr. Ramsower discussed the matter of technical training as follows: "It is worthy of note that technical knowledge, that quality which in a fair degree is indispensable to the success of any agent ranks far below the seven qualities mentioned." This fact is significant. It does not in any sense show that technical knowledge is unimportant or any less important than any one of the other qualities, but it does emphasize the point that no matter how proficient one might be in subject matter, without the seven qualities one would stand little chance of achieving success. This is quite in line with experience and observation in this field of leadership.

The survey indicated that the poor county agent lacked particularly in the following four points: enthusiasm, vision, ability to plan, and initiative. Lack of technical training was not necessariily one of the points in which the poor county agent lacked He did lack though in those very qualities in which the good county agent was strong.

Mr. Ramsower further summarizes the requirements of an extension man as follows: "The extension administrator, the state leader, is vitally interested here. He has learned that the limiting factor in extension teaching today is not *what* shall we teach but *how*." With what telling force does this thought come home to me when I analyze a county in which a limestone project, for example, has been carried on for many years and find how discouragingly small is the percentage of the farmers who are using lime. The fact that the soil needs lime, that it can be economically used, is beyond question. That agent is the great leader who can successfully solve the problem of getting lime on the land. The teaching problem confronting him is not one of passing out information, but one requiring a rich knowledge of the science of teaching, of the tricks of salesmanship, the principles of psychology, the facts of sociology,—it's a case of solving problems in human relationships.

An extension worker must have the rural viewpoint. It is very essential that he understand farmer's problems and be in sympathy with them in their work. Rural districts require leaders who understand farmers and who will work with them in their organizations. Failure to understand the rural viewpoint means loss of contact with the farmers and, as a result, the worker cannot hope to succeed. He must be a leader, not a follower; hence he must have initiative, he must be resourceful and he certainly must possess

* A series of papers presented at the March meeting of the Nova Scotia Branch of the C.S.T.A.

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courage. Difficult problems are constantly requiring attention, and enthusiasm is essential if he is to overcome the many discouragements which are constantly arising.

Organization is one of the essentials of rural districts today. The extension worker who is meeting with the farmers and must give advice in such organizations, must be in a position to make decisions. The extension worker who cannot make decisions, who is not positive, who has no opinions of his own and is not tactful has no place in extension work. One worker will go out in a district, and by his tact and diplomacy will meet difficult situations and create a better feeling between the department and the farmers. Another worker, possibly equally well equipped technically, may antagonize the people by his lack of tact and make it difficult to retain their good will.

We have in people many different qualities; we note a wide range in physical appearance, but there is no less a range in the mental qualities of individuals. Many who are brilliant students at college are not adaptable to extension work, because of their lack of ability to work with people. They may be good students and they may make good men in other positions where the qualities required are different. Agricultural workers are often divided into research and extension workers. The qualities required by the two groups are quite different. It is essential that this difference be recognized. Thus in selecting men for extension work in this province, students are used as assistants to agricultural representatives during the summer months in order to try out these men as to their qualities along these lines and to give them training under experienced men. If not adapted they can turn their activities to other lines; if adapted this training is of decided advantage to them.

## II. Education for Extension and Research Workers

K. Cox *

For both types of workers I feel that the early training should be the same, and should be acquired on the farm. The boy that is raised on the farm will, to my mind, have a more sympathetic understanding of the problems that confront our farmers and be better able to put across any projects which he may attempt. While discussing the question of farm experience, I may say that I do not believe our agricultural colleges should accept time spent on an experimental or college farm as being equivalent to actual farm experience. Six months is all too short under the most favorable circumstances and on an experimental farm, working probably in one or two divisions, the student will have a very hazy idea of conditions as they exist on the average farm. I feel that the experience gained during the winter months, when the live stock are in the barn, is as essential as that of a brief six months during the summer. It is regrettable that our universities are graduating many men whose only farm knowledge is that picked up on an experimental or college farm.

A thorough high school education is essential for both the extension and research worker. Particular attention to English and Mathematics would appear to be necessary. When attending high school, many feel that these subjects are of little interest and will be of little use to them, but when taking university training they find that it would have given them a better understanding of their work.

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I believe that for the first two years the training of research and extension men might well be grouped together, including a grounding in science. This is necessary as very few of us know when we enter a university what line of work we will follow up. The unfortunate situation at present is that many graduates take, of necessity, whatever job is available, regardless of their training.

At the beginning of the third year special courses or options should be provided for the men who intend to take up extension work. These men should be grounded in Economics, Rural Sociology and Psychology. The value of Economics in agriculture is well know and needs no discussion here. The place of rural Sociology and Psychology is perhaps not as generally accepted and I would like to point out that if an extension worker is to be successful, he must know how to approach the farmer and gain his confidence. No two individuals are exactly alike and different methods of approach must be used. A man may be a walking encyclopedia but if he does not know how to get farmers to ask questions and make use of his knowledge, he will not be very successful. I would rather have a man who has a general knowledge of Economics, Rural Sociology and Psychology, than one who has his head crammed full of detailed facts which he may never be able to make use of.

The research worker presents a different problem and his education must be along different lines. He must acquire a knowledge of the necessary technique and learn the care and patience which is necessary in conducting work of an investigational nature. Statistical methods play an important part in research work at the present time and the student who finds his mathematical training deficient will be seriously handicapped in making studies of a statistical nature. It is true I have not been able to make the use of my training in statistical methods that I would like, due to lack of time and facilities, yet it has enabled me to read the work of others more intelligently and has made me more careful in deciding between two treatments in my own work.

The needs of the research worker are fairly well taken care of by our universities, but such cannot be said of the needs of the extension man. Research workers have amassed a wealth of information and it is now high time that we supply special training for those who are taking this information out to the farmers.

After all, colleges do not aim to educate, but rather to develop, and the ssytem that teaches men to use their own initiative should be given preference over a system that simply consists of memorizing facts and returning them parrot fashion to the instructor in the form of examination papers. Teach the student where and how to find information and you will have a more valuable graduate than the walking encyclopedia who is going to be caught napping by the first practical question he is asked.

In conclusion, I might say that four years is all too short a time in which to acquire this education and that both the extension and research worker would be well advised to spend a year or more pursuing graduate studies. By graduation time, he has chosen his particular line and can go in for a more intensive training. Personally I do not believe in taking graduate

work immediately after the Bachelor's degree, but would advocate a few years intervening experience.

## III. Extension Materials

E. L. Eaton *

### Principles

There are several basic principles in the selection of extension material.

1. It must be attractive. In other words it must capture the interest of the persons to whom the appeal is made.

2. It must reach the largest possible number at the lowest possible cost. In every instance low unit cost is the objective.

3. It must be suited to the particular problem or group aimed at; thus a different selection of material is necessary for junior and adult groups, for districts where the educational standards vary, or where different racial groups occur.

### Materials

The following materials are in more or less common use. All have advantages and faults.

1. *Bulletins.*— Far too many so-called bulletins are not bulletins but text books. Text books have an important place in the class room, but not for general distribution. The term "bulletin" implies news and as a source of such should preferably be brief and concise. Technical articles today are not considered complete without a summary and where a farmers' bulletin exceeds the length of a short story, a summary and list of contents should be included.

2. *Charts.* (a) Long tables of figures are difficult to follow and are rarely understood. If figures are used they should be condensed and only the main features stressed.

(b) Graphs are more easily followed than figures, but are only effective with people of fair education.

(c) Colored charts for the purpose of illustrating special work (such as meat cutting, times for spraying and other practical problems) are excellent substitutes when the actual objects are not available.

3. *Samples.*—Actual specimens such as sheaves of grain and forage crops, weed seed collections, Riker mounts, individual birds or animals, and so forth, are among the very best means of illustrating points under discussion.

4. *Posters.*—(a) For advertising meetings, posters are effective if they can be put up in a general meeting place. In these days of cars, roadside posters are practically worthless.

(b) Decorative posters, if done in an artistic blend of colour, can be used to further special programmes, such as weed control, crop improvement, or pest prevention. Their chief value is in the schools, and their longevity is in direct ratio to their attractiveness.

5. *Demonstrations.* Two types of demonstrations are in use:

(a) *Direct.* In this the extension worker or specialist teaches a lesson in some special process (as packing poultry, thinning fruit, castrating, etc.). Such demonstrations should teach the individual to do these things himself, not lead him to think that he is supplied with a hired man gratis.

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(b) *Indirect.* In this a lecture, dialogue or special piece of work is presented by some junior member or members, previously coached by the extension worker. Simple charts and other illustrations may be used. This is one of the most effective means of conveying a message to an adult group and at the same time popularizing the extension work.

6. *Motion Pictures and Lantern Slides.* The old adage "Seeing is believing" is just as true today as ever. It is not always practical to take farmers to see fertilizers or crop demonstrations, but it is entirely feasible to take these fields to the farmer. Incidentally, it is possible to assemble data from a much wider area and arrange it to make a thoroughly connected story for use at a farmers' meeting.

7. *Radio.* It is difficult to know how many people tune in on agricultural lectures. There is conclusive evidence that markets, crops and weather reports are all largely sought and in no other way can as up-to-the-minute data be furnished.

## IV. Extension Methods

A. F. Curran *

In dealing with the question of extension methods it is difficult to lay down hard and fast rules for extension men to follow. Circumstances are somewhat different in practically every county or province and a method that will produce good results in one area may not do so in another. It depends very largely on the ability of the extension worker to judge which method is best. The object of extension in agriculture is to carry to the great mass of people engaged in agriculture the findings of Experimental farms and Agricultural Colleges. This cannot be done direct from these institutions, but must be passed on to the extension specialist who co-operates with the county agent in carrying the practice into effect.

If an extension agent could visit every farm home to discuss agricultural problems it is likely that the best results could be accomplished, but with the limited number of men engaged in this work this is impossible. While it is admitted that it is necessary for visits to be made to a certain number of farms to encourage the practice of better farming in order that effective examples may be available, yet the large percentage must be reached through other mediums. An appreciation must be developed for this information, or in other words, our material must be sold to the public. The question then arises which is the best means of doing this.

According to a survey conducted in the United States in seventeen States, these States had 43.8% of the extension workers and 46.4% of the total extension budget for the United States for the year ending June 30, 1928. News service gave the highest returns per unit of cost with 2.79 practices adopted. Next to news service stood another publicity item, namely, circular letters with 1.82 practices adopted per unit of cost. Exhibits gave the lowest return per unit of cost with .18 practices adopted. Extension schools came next to exhibits with .34 practices adopted per unit of cost. General meetings came fairly high, standing next to circular letters with 1.72 practices adopted per unit of cost. Office calls stood at 1.56, bulletins 1.40, farm or home visits 1.13, leader training and method demonstrations 1.04, result of demonstrations .47, correspondence .45 and telephone calls .44.

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The results of this survey indicate that publicity obtains results at the least cost. Might I mention that to be effective it must be interesting and useful, and above all not too long, with as few technical words as possible?

The results obtained by general meetings may require some explanation. School fairs, club fairs, club field days, co-operative marketing meetings and general meetings were grouped under this heading.

Where possible, uniformity of policies simplifies many of our marketing problems. To illustrate the point, should we not have uniform grade names for all agricultural products? Both producer and consumer to-day are confused with the lack of uniformity in the names of the grades that are supposed to identify the various stages of quality in agricultural products. Would not a colour scheme, such as, blue for the first grade, red for second and green for third, convey to both producers and consumers the various stages of quality in these products?

Is it not also possible for us to carry our extension work to the consumer and ascertain his preferences, and by salesmanship obtain for that preference a premium that reacts back to the farmer responsible for the quality product that meets this preference? I cannot think of anything that would be a better selling proposition than the linking up of the production and marketing of a product of high standard that meets with sufficient appreciation on the part of the consumer to justify him paying a premium for it, and with the adoption of uniform standards this policy could be applied in a very broad way.

## Summary

Following the presentation of these papers and the subsequent discussion, the following resolutions were adopted and forwarded to the Educational Policies Committee of the C. S. T. A.

1. That specialized Courses be offered at our Agricultural Colleges for Extension and other Field Workers, both as under-graduate and graduate options.

2. That studies of Extension and Field Workers' methods be made, including a survey of those now in practice in the Dominion.

3. That an effort be made to better correlate the work of Extension and Field Workers, and to improve their contact with both Educational and Research Institutions.

4. That an effort be made to procure for the use of Extension and Field Workers further suitable illustrative materials and publications.

5. To urge upon Extension and Field Workers the necessity of contributing articles relating to their work to the Society's official organ *Scientific Agriculture*.

### Revisional Note

In the article on "Purity Concepts with Respect to Crop Varieties" which appeared in the March 1931 issue of *Scientific Agriculture,* Dr. J. B. Harrington desires to substitute for the last three lines on page 412 and the first three on page 413 the following: cent, and in twenty years only 99.98 percent. Thus at the end of twenty years the chances of any particular individual being almost fully homozygous would be very large, and a line commenced from such an individual would, of course, be highly *homogenious* as well as highly *homozygous,* that is to say it would have a high degree of purity. By "highly homogenious" I mean having a very close genetical similarity between plants. There is no test known by which one could determine exactly how homozygous and homogenious (i.e. pure) a given line is. Theoretically it is quite possible that any given line might be much less *pure* than 99.99 per cent, which is the standard of purity used by the Canadian Seed Growers' Association for registered seed with respect to observable morphological characters of the parent plants.

### Footnote Correction

In the article entitled, "Studies on the effects of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc," by G. B. Sanford and W. C. Broadfoot, the authors desire to make a correction in the last two lines in the footnote for Figure 2 as follows: •, Average height of plants—culture or filtrate plus the pathogene. °, Average height of plants—culture or filtrate alone.

## NOUVELLE SECTION DE LA C. S. T. A.

Dans le courant du mois d'avril s'est formée une nouvelle section de la C.S.T.A. qui sera connue sous le nom de "Section de Montréal-Ville" (Montreal City Local Branch). Les délibérations de la nouvelle section seront bilingues. Les officiers en sont: Président, M. B. Leslie Emslie; Vice-Président, M. Henry E. Lefèvre; Secrétaire anglais, M. O. R. Evans; Secrétaire français, M. Robert Raynauld.

La nouvelle section a été crée pour répondre à un besoin résultant de la situation particulière qu'occupe la ville de Montréal dans le Dominion. Il est bien entendu que la nouvelle section ne dérangera en rien les sections déjà existantes de Montréal et de Macdonald, lesquelles continueront d'avoir leur existence propre et les mêmes activités que par le passé. Loin de vouloir se développer aux dépens des sections déjà existantes, la nouvelle section entend exercer ses activités dans des champs d'action peu touchés, contribuant ainsi au plus grand développement de la C.S.T.A. en général et par contrecoup de toutes les sections déjà existantes.

A sa première réunion officielle, le mercredi 22 avril, la section de Montréal-Ville a eu l'honneur d'avoir plusieurs visiteurs de marque, tous membres de la C.S.T.A.: L'Hon. John S. Dash, Directeur de l'Agriculture en Guyane Anglaise, le Dr. Louis-Philippe Roy et M. Henri Bois du Ministère de l'Agriculture à Québec.

La section de Montréal-Ville, continuant l'initiative prise par les membres habitant la ville de Montréal avant la formation de la section, tiendra des déjeûners hebdomadaires au Restaurant Krausmann's, Carré Phillips, tous les mercredis à midi et demi, heure de la ville, déjeûners non formels auxquels sont cordialement invités tous les membres de la C.S.T.A., à quelque section qu'ils appartiennent..

# IMPRESSIONS D'UNE VISITE A QUELQUES INSTITUTIONS AGRICOLES DE FRANCE ET D'ANGLETERRE

A. Geo. Gilbert*

Un an et plus s'est écoulé depuis que les notes formant le fond de cet article ont été recueillies. S'il n'eût tenu qu'à l'ambition de l'auteur, elles auraient légitimement dû être publiées dès le retour ; cependant les circonstances ne l'ont pas permis, et c'est un surcroît de travail quotidien qui en a différé la rédaction jusqu'à ce jour.

Quoique n'ayant plus la même saveur de fraicheur, elles ont tout au moins la valeur d'être inédites et constituées par des observations personnelles ouvertes à la critique du lecteur.

Un des derniers passagers, mais certainement le plus illustre, à franchir la passerelle de l'Empress of Australia à Québec, fut le prince Henry, troisième fils du Roi George, qui revenait de son ranch de High River dans l'Alberta.

Les introductions sont rapides et favorisées par un ciel et une mer idéals. Il arrive souvent que plusieurs trouvent la traversée trop courte ; néanmoins au sixième jour il nous fallut quitter à Cherbourg notre palais flottant. Une fois en route pour Paris on ne tarda pas à se rendre compte que la récolte de céréales en France était excellente, de fait la plus forte enregistrée depuis 25 ans.

## La Station Expérimentale de Rothamsted

Connue aussi sous le nom de "Lawes Agricultural Trust", située à Harpenden, dans le Hertfordshire, à 25 milles de Londres, la plus vieille station expérimentale anglaise dont le nom est fameux aux quatre coins du globe est d'accès très facile au visiteur quittant la capitale par la gare de St. Pancras.

Le fondateur de la station fut Sir John Lawes qui traça les champs d'expérience sur sa propre ferme, en 1843. Dès le début, il s'adjoignit les services d'un jeune chimiste appelé à devenir plus tard Sir Henry Gilbert, lequel devait s'occuper du côté scientifique. Pendant tout le temps qu'ils furent associés, les expériences furent conduites aux frais de Sir John Lawes et, avant sa mort, il prit les dispositions nécessaires pourvoyant aux fonds pour le futur. Au temps de Lawes et Gilbert le travail était très diversifié. Les problèmes de nutrition animale aussi bien que l'alimentation des plantes étaient sous investigations et recherches chimiques. Leurs analyses de carcasses d'animaux, à différentes périodes de croissance, sont devenues classiques, tandis que le succès dont ils ont été témoins en voyant les fermiers anglais adopter les résultats de leurs travaux sur la nutrition des plantes se juge par le rapide développement de l'industrie des engrais chimiques en Angleterre.

Après la mort des deux associés, de 1902 à 1912, le travail de la station fut sous la direction de Sir A. D. Hall, et c'est en 1913 que le présent directeur Sir John Russell fut appointé.

Le travail poursuivi à Rothamsted est aujourd'hui divisé en deux parties, les champs classiques et les expériences modernes multipliées. Les champs classiques, sur lesquels on a cultivé les mêmes récoltes en succession depuis 1843, ont permis la démonstration la plus frappante de l'effet des engrais

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chimiques. Le fameux champ "Broadbalk" a été continuellement en blé; le "Barnfield" a été affecté aux racines, en 1856 le "Park Grass" au foin. Ces expériences, commencées dans un temps ou l'engrais de ferme était le principal agent connu pour maintenir la fertilité des sols, eurent un retentissement considérable et, comme résultats pratiques, l'introduction du superphosphate, sulfate d'ammoniaque et nitrate de soude, ainsi que l'obtention de données quant à leur emploi judicieux et l'affirmation de la théorie que les engrais artificiels étaient le complément de l'engrais de ferme. Quelques résultats d'importance pratique obtenus à la suite de la longue expérience poursuivie avec les engrais chimiques sur les plantes fourragères au "Park Grass Field" méritent d'être rapportés ici, car c'est le seul endroit au monde où l'on a un champ dont la dernière date de semis remonte à 1856. (Fig. 1).

Figure 1. Station de Rothamsted—Partie du "Park Grass field" montrant l'influence des engrais chimiques et de la chaux sur la pousse continue de l'herbe depuis 1856.

a.—L'emploi d'engrais de ferme et d'engrais chimiques affectent énormement la quantité et la qualité du foin. La flore est modifiée et les espèces nuisibles composant la prairie son généralement réduites.

b.—Les engrais à base d'azote favorisent une pousse hâtive. Employés continuellement sur les pâturages ils favorisent le développement des graminées, aux dépens des trèfles.

c.—Les engrais phosphatés et potassiques combinés augmentent la proportion des légumineuses.

d.—Les engrais chimiques complets, (avec chaux lorsque c'est nécessaire) et l'engrais de ferme donnent les plus grosses récoltes de foin.

e.—Les parcelles ne recevant aucun engrais produisent une herbe coriace, bien souvent dédaignée par les animaux, et fournissent un excellent contraste en faveur des parcelles traitées.

Les expériences modernes multipliées diffèrent totalement des séries classiques. Les vieilles expériences avaient le mérite d'être simples mais devaient être poursuivies longtemps avant que l'on puisse compter leur résultat

comme définitif. L'erreur expérimentale était grande, principalement à cause de la variabilité du sol et c'est pour diminuer ces chances d'erreurs que l'on commença en 1912 les expériences nouvelles, analogues quant aux méthodes générales à celles poursuivies en notre pays.

Aucun travail expérimental n'est entrepris en Industrie Animale, bien que l'on garde sur la station: bovins, moutons et porcs dans le but de faire pâturer les prairies et d'obtenir de l'engrais de ferme.

Le laboratoire de biométrie a un rôle particulièrement important à Rothamsted. Son but principal est de diminuer les possibilités d'erreurs trop généralement possibles lorsque l'on se base seulement sur les résultats actuels obtenus sur des parcelles de petites dimensions multipliées souvent 6 et 8 fois.

Il coopère et coordonne les travaux de recherches de grande culture en ce sens qu'il interprète et en analyse systématiquement les résultats et, si l'on est tant soit peu au courant des méthodes scientifiques d'expérimentation, l'on comprend que c'est la tâche la plus ardue mais aussi le plus utile. Tandis qu'en Amérique on emploie la méthode connue sous le nom "d'erreur probable", à Rothamsted, ils préfèrent "l'erreur standard", et en 1925 le Dr. R. A. Fisher, chef du laboratoire, aidé de ses huit assistants, a développé ce qu'il appelle "The Variance Method of Analysis".* Cette méthode s'appliquant aux essais sur parcelles gagne rapidement en faveur. Elle combine la simplicité, la facilité de calcul et le plus haut degré de précision qui puisse être obtenu. Un tel critérium est un outil plein de pouvoir entre les mains de l'investigateur.

La Station de Rothamsted comprend onze divisions avec un total d'au delà de 70 techniciens. En ces dernières années, la station a été agrandie grâce aux subventions du Ministère de l'Agriculture et aujourd'hui les activités de Rothamsted ne sont pas confinées seulement aux Iles Britanniques, mais s'étendent graduellement à l'Empire entier et aux autres nations.

### Station d'Essai de Semences à Cambridge

Connu sous le nom de "Official Seed Testing Station for England and Wales", situé à Cambridge et avoisinant l'une des plus vieilles Universités anglaises, ce laboratoire conduit les essais de pureté et de germination sur les semences destinées au commerce domestique et à l'exportation. (Fig. 2).

Travaillant en étroite coopération avec "The National Institute of Agricultural Botany" le laboratoire de Cambridge utilise avantageusement les quelques acres de terre arable qui l'entourent en conduisant des expériences sur la rusticité et l'adaptabilité des trèfles d'origine étrangère ainsi que sur la détermination de la pureté d'échantillons douteux quant à la variété. C'est du moins ce qu'il y avait en cours lorsque je suis passé là. L'essai des céréales aussi bien que la création de nouvelles variétés sont l'objet d'une attention toute spéciale de la part du Directeur de la Station, M. Alfred Eastham. (Fig. 3). En 1929, 30.000 échantillons furent reçus pour analyse à Cambridge. A titre de référence, les échantillons analysés sont conservés pour au moins un an.

Je tiens à noter quelques particularités qui pourraient être utiles à ceux spécialement intéressés dans l'analyse des semences. Les brassicas et les panais sont plantés en deux lots de 200 chacun, l'un dans le sable, l'autre

* R. A. Fisher, Statistical Methods for Research Workers. Oliver and Bond Co., London, 1925.

entre buvards, et le pourcentage de la germination est donné suivant la moyenne des résultats obtenus. Les pois sont plantés dans le sable à raison de 25 graines par pot. L'essai est répété 6 fois. On compte 500 graines pour les carottes et de 500 à 800 pour les betteraves; on a aussi trouvé que l'une des semences qui perdent le plus rapidement leur faculté germinative serait la graine d'oignon diminuant jusqu'à 30 pour cent en 3 ou 4 mois.

Figure 2. Vue partielle de la Station d'essais de semence de Cambridge, Eng.

Figure 3. Station d'essais de semence—Cambridge. A noter la vigueur de la luzerne et du sainfoin. Les cages entourant les céréales servent à prévenir les croisements et mélanges des variétés.

La visite à Cambridge fut des plus agréables en même temps qu'éducative car, par une heureuse coincidence, j'y ai retrouvé en M. Eastham, l'analyste en chef des Semences à Ottawa jusqu'en 1922. Nous avons profité de l'occasion pour parler un peu du pays.

## Royal Botanic Gardens, Kew

Les jardins botaniques de Kew, situés dans un faubourg ouest à quelques milles du centre de Londres, sont d'accès si facile que c'est le lieu de promenade favori des Londoniens lorsque le travail cesse. Qu'il suffise de dire que le nombre de visiteurs aux jardins en 1928 fut de 1,127,003. La semaine, l'entrée est gratuite à l'exception des porteurs de kodak qui doivent payer 6 pences pour leur appareil.

"Kew Gardens", comme on dit couramment là-bas en langage abrégé, est la plus vieille institution du genre au monde. Ils couvrent plus de 280 acres et il n'y a pas très longtemps, on pouvait encore admirer un magnifique orme, planté au temps de Frédéric (Prince de Galles 1730-1751). Cet arbre, de 100 pieds de long et de 18′ à la base, probablement le plus haut du jardin, fut déraciné par un gros orage en novembre 1928.

Les premiers rapports annuels furent publiés en 1887. En 1895 on publia l'Index Kewensis,—2500 pages—lequel est coté à l'heure actuelle comme la plus complète énumération des genres et espèces de fleurs depuis Linné jusqu'en 1895, contenant le nom des auteurs, le pays de publication des travaux originaux, et les synonymes.

Accompagné du Directeur, Dr. Hill, j'ai dû passer un peu rapidement des serres aux laboratoires, et des parterres de fleurs aux muséums (Fig. 4).

Les bibliothèques contiennent des milliers de volumes et les herbiers jamais terminés, pour la bonne raison qu'ils s'acroissent de jour en jour, comptent des milliers d'espèces différentes. C'est là que j'ai eu le plaisir de faire la connaissance de M. C.V.B. Marquand, du "Welsh Plant Breeding Station" à Aberystwyth et auteur d'un fameux travail sur "Varieties of oats under cultivation".

Figure 4. Serres et parterres aux "Royal Botanic Gardens, Kew".

Kew, par l'entremise de ses correspondants étrangers, est en relation avec tous les pays du monde et reçoit chaque année un nombre considérable d'érudits botanistes qui y séjournent quelquefois plusieurs mois en vue de se perfectionner dans l'étude de certaines espèces. Les Etats-Unis ont commencé

la création d'un jardin semblable mais il est douteux que Kew puisse être jamais égalé.

### Paris et l'Institut Agronomique

Ma première visite fut pour le Ministère des Affaires Etrangères, Quai d'Orsay, dans le but d'obtenir une réduction sur les taux de transport des grands réseaux français. Grâce à l'obligeance du Comte Fleury du service de la presse étrangère et à titre de représentant du journal "Le Droit" d'Ottawa, il me fut relativement facile d'obtenir les lettres m'accréditant auprès des compagnies pour les autoriser à faire une réduction de 50 pour cent.

Qu'il me soit permis de remercier ici le Dr. J. H. Grisdale, Sous-Ministre fédéral de l'Agriculture, pour les lettres d'introduction qu'il avait bien voulu me donner en vue de me faciliter l'accès aux différentes stations agricoles. Elles ne me furent nulle part plus utiles qu'à l'Institut Agronomique où, suivant "le vieil esprit de routine français", il est nécessaire de montrer des lettres de crédit.

Mathieu de Dombasle créa en 1822, près de Nancy, la première école d'agriculture digne de ce nom, et en 1848 l'Institut agronomique était établi à Versailles, supprimé brusquement en 1852, et reconstitué à Paris en 1876.

M. Jean Hennessy qui était en 1929 Ministre de l'Agriculture, et incidemment fabricant du fameux cognac qui porte son nom, restera sans aucun doute célèbre dans les annales de l'Institut Agronomique. En effet c'est sous son régime que fut construite la nouvelle aile logeant les laboratoires de chimie modernes et deux spacieux amphithéatres servant aux cours et démonstrations.

Mon arrivée à l'Institut agronomique coincidait avec les examens finaux, et là j'ai connu la fièvre typique des "bacs" au quartier latin.

Accompagné de M. J. Cuvillier, de la division de la Grande Culture, j'obtins de précises informations sur l'enseignement donné. L'Institut tire un grand bénéfice d'un certain nombre de stations qui lui sont annexées et qui sont dirigées par ses professeurs, entre autres, les stations de semences, d'essai de machines, d'entomologie, de viticulture, etc.

Les études très approfondies de chimie que l'on poursuit à l'Institut Agronomique pendant les 2 années réglementaires et pendant la troisième année d'études complètent la pratique scientifique que l'on a pu acquérir dans les laboratoires de botanique et de microbiologie. Jointes aux visites et excursions aux grandes exploitations agricoles aussi bien qu'à la station de Recherches agronomiques à Versailles, ces études préparent particulièrement bien les élèves.

Comme le programme d'études ne comporte pas de travaux manuels pratiques,—l'Institut de par sa situation rendant impossible tout contact direct avec les choses de la terre.—on essaie d'y remédier à la fin du cours par des stages consacrés pendant un ou deux ans à la pratique agricole.

Les emplois administratifs deviennent de plus en plus rares en France et les jeunes diplômés doivent se diriger vers la vie rurale. D'après une statistique établie le 1er janvier 1925 sur les 3,056 anciens élèves de l'Ecole, 1,250 environ, soit 41 pour cent s'occupent d'agriculture pratique, 364 sont engagés dans l'exploitation forestière, 212 font de l'enseignement agricole, 175 sont des fonctionnaires, et 330 se sont adonnés au commerce et à l'industrie.

### Le Laboratoire des Semences—Paris

M. E. Schribaux, Professeur de Botanique à l'Institut agronomique et auteur du manuel que plusieurs connaissent pour l'avoir eu comme livre de texte, est aussi Directeur de la Station des Semences de la rue Platon. Le laboratoire est central pour toute la France et n'analyse que les semences. C'est en 1894 que l'on commença à s'occuper du contrôle des semences: l'agent du service de la répression des fraudes visite les commerçants, prélève quatre échantillons dont deux sont envoyés à la préfecture la plus voisine, un au laboratoire de Paris, le quatrième est laissé au marchand. Il est permis de livrer et d'offrir en vente des semences d'une pureté faible, en autant que le vendeur indique le pourcentage de pureté sur l'étiquette.

Avec un personnel composé d'un directeur, de deux chefs de travaux et de quinze analystes, le laboratoire a, en 1929, analysé 16,200 échantillons. Il est intéressant ici de revenir au Canada et de faire une comparaison sur l'efficacité et la perfection de notre Loi des Semences telle qu'appliquée par le Département d'Agriculture. Actuellement, il y a sept laboratoires en opération dans le Dominion, lesquels ont reçu pour fins d'analyse, en 1930, un total de 59,799 échantillons.

Les principes guidant les essais de germination et analyses de pureté étant pratiquement les mêmes que ceux adoptés par l'Association des Analystes Officiels d'Amérique, nous ne donnerons guère plus de détails. Mentionnons toutefois que le trèfle d'odeur (mélilot jaune) est considéré comme mauvaise herbe, et que dans le cas des céréales, on préfère le poids de 1,000 grains au poids de l'hectolitre, lorsqu'il s'agit de déterminer la qualité intrinsèque du grain par l'apparence générale. Ce dernier point de vue est d'ailleurs partagé par les classeurs canadiens.

### Station Centrale d'Amélioration des Plantes

Située à Versailles, pas très loin du fameux Château, cette station n'a guère plus de cinq ans d'existence. Par sa situation et la disposition générale des différents laboratoires, aussi bien que des parcelles d'expérimentation, elle rappelle quelque peu le Collège Macdonald. Le station est très moderne et indique clairement que l'on n'a rien épargné pour en faire un centre de recherches pourvu de tout le matériel nécessaire. Sur ce point, elle se compare des plus avantageusement aux institutions américaines. Par ailleurs, n'ayant pas duré un nombre d'années suffisant, on ne peut raisonnablement s'attendre à ce qu'à date les projets d'expérience et les résultatts obtenus aient atteint le même niveau que ces dernières. Cependant, l'auteur est convaincu que les travaux qui dans l'avenir s'effectueront à cette station occuperont une place primordiale dans les recherches scientifiques agronomiques du monde.

Au laboratoire de grande culture on développe activement les recherches sur les céréales sous la direction immédiate du Directeur de la station, le Dr. Schribaux. Les nombreux hybrides issus de croisements et les sélections sont multipliés suivant la méthode connue ici c'est-à-dire en "head-rows" et "rod-rows".

Dans les travaux d'expérimentation sur les céréales, où l'on a un nombre considérable de variétés, en France comme au Canada et aux Etats-Unis, les expérimentateurs ont à éviter le danger des mélanges lors du battage. Dans

Figure 5. Station centrale d'amélioration des plantes—Versailles. Petite batteuse mobile.

Figure 6. Station centrale d'amélioration des plantes—"Head-rows" et "Rod-rows" de blé. Le laboratoire affecté aux recherches sur les céréales.

ce but la station a construit trois petites batteuses mobiles (Fig. 5) à cylindre se composant de dix raies transversales et de nettoiement très facile. Cette petite batteuse combine l'efficacité avec la simplicité et a le grand avantage de supprimer le danger des mélanges qui peuvent advenir lorsque l'on conserve ces gerbes pour battage au laboratoire.

Le laboratoire de Pathologie végétale sous la direction du Professeur Foëx fait des recherches sur le piétin, la rouille, le charbon, la carie, ainsi que sur la pourriture de la tige du trèfle.

La France produisant beaucoup de betteraves sucrières, il y a de nombreux projets portant sur l'augmentation du pourcentage de sucre des variétés actuelles et sur les méthodes de culture s'y rapportant, telles que l'écartement entre les rangs, sur le rang, etc. . . .

La station étant aussi le siège social de l'Association Internationale des Sélectionneurs de Plantes de grande culture, (Fig. 6), le président, Dr. Schribaux, m'enrôla comme l'un des membres. Avec M. L. H. Newman, Céréaliste du Dominion, nous sommes les deux seuls représentants du Canada. Si quelques membres de la C.S.T.A. intéressés dans cette spécialité, désirent devenir membres, je leur fournirai avec plaisir les formules nécessaires.

Le cadre limité de cet article ne me permet pas de rentrer dans de plus longs détails. Qu'il me soit permis de prédire qu'avec des autorités agronomiques telles que l'on a placées en tête de chaque département et une installation qui permet des recherches poussées à fond, la station centrale d'amélioration des plantes fera du bon travail lequel aura son écho de ce côté-ci de l'Atlantique, ce qui sera une forte contribution à la science des plantes.

## Conclusion

On m'a souvent demandé si nos deux écoles françaises du Québec pouvaient se comparer avec l'Institut Agronomique de Paris. C'est un point délicat. Cependant en faisant la part des choses, je crois que nos Collèges d'Agriculture et plus spécialement celui de Ste-Anne de la Pocatière, pour rester dans un domaine connu et comparatif, se comparent avantageusement. Pour avoir eu l'avantage, grâce à feu l'Honorable M. Caron—qui m'y dirigea —de poursuivre mon cours au plus ancien Collège Agricole du Canada, je suis d'opinion que pour former des agronomes, des propagandistes et enfin tous ceux qui sont engagés dans un travail d'extension, le Collège de Ste-Anne de la Pocatière est au moins l'égal de l'Institut Agronomique.

D'un autre côté, pour la formation de spécialistes dont le travail consiste à conduire des recherches en science appliquée, l'Institut Agronomique par son enseignement de grands maîtres l'emporte.

Pour ceux qui aiment en temps opportun joindre le plaisir à l'étude, je ne peux mieux faire que de leur suggérer de devenir les hôtes d'une Duchess ou d'une Empress du Pacifique Canadien. Les éloges sur le confort, l'efficacité du service et la courtoisie du personnel de cette compagnie seraient superflus. La classe que l'on coudoie sur ces bateaux est la meilleure, et aussi c'est sous ces conditions que l'on trouve l'atmosphère—ce mot, au figuré, si enchanteur par ce qu'il évoque et que les anglais ont adopté dans leur vocabulaire—idéale pour nouer une idylle.

Une vacance agréable pour plusieurs d'entre nous pourrait bien être la traversée de l'Atlantique avec quinze jours en Europe. C'est suffisant. Un tel voyage laisse dans l'esprit la marque des choses vues tellement plus fraîches et plus fécondes que les choses écrites et raisonnées.

## CONCERNING THE C.S.T.A.

### Programme for Guelph Convention

The programme for the Eleventh Annual Convention of the C.S.T.A. to be held at Guelph from June 22nd to 26th will be in the mail in a few days. It remains much as outlined in recent issues of *Scientific Agriculture*. While the opening session of the convention is at 9 a.m. on Tuesday morning, June 23rd, there will be committee meetings and Director's meetings on Monday the 22nd. In addition to this the Ontario Agricultural Representatives will be in session and the Canadian Phytopathological Association will open its convention on that day also. The members of the C.S.T.A. are invited to attend the dinner of this association on Monday evening at 7 p.m. Following the dinner there will be a special lecture by Dr. J. G. Dickson of the University of Wisconsin who will speak on, "Agricultural development in Soviet Russia and its relation to the wheat problem." Dr. Dickson will also lecture to the Phytopathologists during one of their afternoon sessions.

Group sessions in Economics, Animal Production, Soil Science and Horticulture will be held on Tuesday afternoon and Wednesday morning at Guelph. Open lectures will be given on Tuesday by three special lecturers. The first of these, Dr. J. B. Orr, D.S.O., M.C., M.D., D.Sc., of the Rowett Research Institute, Bucksburn, Aberdeen, Scotland, is expected to speak on animal nutrition. Dr. Orr has consented to come if satisfactory arrangements can be made to release him from his duties in Scotland in time to reach the convention. He is Director of the Imperial Bureau of Animal Nutrition. Dr. H. M. Tory, Director of the National Research Council, will speak on the work of that organization. The third speaker will be Dr. O. C. Stine, President of the American Farm Economics Association who will present an analysis of the various theories regarding the cause and cure of the present agricultural depression.

At the open session at the Vineland Horticultural Station on Thursday afternoon Dr. D. F. Jones, Geneticist at the Connecticut Agricultural Experiment Station, New Haven, will speak on "The Efforts of Science to Increase Food Resources." Many other speakers will be found listed on the programmes of the various group sessions.

The Ontario Government banquet will be held in the Refectory overlooking Niagara Falls on Wednesday evening, June 24th. The Ontario Agricultural College Banquet will be held in Creelman Hall on Thursday evening, June 25th. Friday, the 26th, will be given to reports of the C.S.T.A. committees and other important business. O. A. C. class reunions will be held on that evening and the Annual Alumni Day on Saturday.

### Grindley Memorial Portrait

Members of the C.S.T.A. are reminded that branch secretaries will shortly send in their contributions for the Memorial Fund. These must be in the hands of the General Secretary before the close of the Society year on May 31st.

Excellent progress has been made on the portrait, and the committee and Mrs. Grindley feel that Mr. E. Wyley Grier will have a very satisfactory

picture ready for the convention. The unveiling ceremony will take place in the Memorial Hall at Guelph on Tuesday evening, June 23rd at 9 p.m. Daylight Saving Time.

### O. A. C. Class Reunions

In connection with the C.S.T.A. convention at Guelph several classes are planning reunions on the 26th of June. Members of the year 1905 are requested to get in touch with A. W. Mason, O.A.C. The 1911 reunion information will be supplied by J. C. Steckley, O.A.C., and the 1921 reunion by H. A. Smallfield, O.A.C. No doubt other classes who have not supplied us with definite information will also hold reunions. We will be glad to announce any additional ones in the June issue of *Scientific Agriculture*.

### Convention Accommodation

Through arrangements with the Ontario Department of Agriculture and the Ontario Agricultural College accommodation for the coming C.S.T.A. convention has been arranged for at the very reasonable rate of $2.00 per day or $10.00 for the convention week. This includes board and room, single beds, two in a room. The flat rate of $10.00 for the week includes free transportation to Niagara Falls for those without cars and includes also hotel accommodation at Niagara Falls on Wednesday night. This very generous arrangement is made possible because of the decision of many Ontario members to register for the full week regardless of whether they will be in residence during the full session or not. It is to be hoped that C.S.T.A. members and their wives will take advantage of this opportunity to combine business and pleasure and will register in considerable numbers for the convention. A special programme has been provided for the ladies including a free drive to Toronto on Tuesday, June 26th.

At the O.A.C. banquet on Thursday evening dress will be optional; at the Banquet at Niagara Falls on Wednesday evening, and on all other occasions, dress will be informal. For the information of those who expect to attend and may have doubts on this point, the majority of those in attendance will be in informal dress on all occasions.

### Canadian Seed Growers Association Convention

The C.S.G.A. announces the following tentative programme for their convention in Kemptville and the Ottawa Valley:

Monday and Tuesday, June 15th and 16th:

Plant Breeder's committee meetings and Director's meetings.

Wednesday, June 17th:

General Session with business and lectures.

Thursday, June 18th:

A tour through the Ottawa Valley including the Central Experimental Farm.

Friday, June 19th:

Special lectures and features of interest to local seed growers.

Saturday, June 20th:

Reserved to complete unfinished business.

Attractive accommodation and entertainment will be provided at the Kemptville Agricultural School at very reasonable rates.

## C. S. T. A. Elections

Ballots for the election of the officers of the C.S.T.A. for the year 1931-32 were opened on April 20th at the Society headquarters. A total of 824 members voted with the following result:

President—H. S. Arkell, Canadian Live Stock Cooperative Ltd., Montreal.

Vice-President—G. I. Christie, Ontario Agricultural College, Guelph, Ont.

Vice-President—Hon. J. A. Godbout, Minister of Agriculture, Quebec.

Honorary Secretary—L. H. Newman, Central Experimental Farm, Ottawa.

## The First International Conference of Technical Agriculturists, Rome, November 23 - 27, 1930.

F. T. Wahlen *

Why another international body? And why an International Federation of Technical Agriculturists?

We seem to be living in the age of international conferences. Not only in politics, but in every sphere of activity there is an ever increasing feeling that the time is past when problems can be solved nationally, because through economic and intellectual intercourse the interests of countries and continents are so much interlocked that we have learned to consider even our antipodes as our neighbours. If proof had been lacking that this is so it could not have been furnished more strikingly than through the present economic depression, which makes the Canadian wheat farmer suffer because of the lack of purchasing power of the forced-to-be-idle European industrial worker, and which makes the repercussions of Indian or Chinese unrest felt the world over inside of a few weeks.

It is a fine thing that science should have taken the lead in international collaboration, and a particularly hopeful indication is the fact that agricultural science is not lagging behind her sisters in the endeavour to further the interests of humanity regardless of boundary, language and race. We are so little aware of the great changes brought about during the last two decades, and forget so often that international good-will must be sought and found little by little, that sometimes we are inclined to consider additional efforts as useless and wasteful. It is only when we think of the enormous toll in blood and money that were foolishly spent in forcing the nations of the world apart during the last war that we come to realize our responsibilities towards the generations to come in trying to re-establish former good relations, and in making the world safe against another catastrophe.

This is why I welcomed, in spite of initial misgivings, the invitation to the First International Conference of Technical Agriculturists. And I was particularly glad to accept the invitation of the executive of the Canadian Society of Technical Agriculturists, to go as the representatives of this society, because it is in itself an outstandnig and fine example of men of two races and languages working harmoniously towards the same goal.

*Dr. Wahlen, formerly Chief Seed Analyst of the Dominion Department of Agriculture at Ottawa, and now Director of the Agricultural Control and Experiment Station at Oerliken, Zurich, Switzerland, acted as delegate of the C.S.T.A. to this conference.

The idea of forming an International Federation of Technical Agriculturists first took shape in 1929, during the proceedings of the XIV International Congress for Agriculture in Bucarest. At this occasion a resolution was presented to the committee on rural economy and politics, pointing out the desirability of forming such a federation, and this resolution was unanimously approved. It was then decided to hold the organizing conference in Rome, and the Italian Federation of Technical Agriculturists, through their secretary-general Dr. Franco Angelini, accepted the task of organizing this conference and of preparing a draft of statutes which was to serve as a basis of discussion. Twenty-four different countries were represented by the delegates of national associations when the conference assembled on November 24, 1930, for the opening session presided over by the deputy minister of Agriculture of Italy, His Excellency Arturo Marescalchi.

Mr. Marescalchi delivered a very inspiring address of welcome, in which he touched on the grave situation the agriculture of the world is facing today, and pointed to the responsibilities of the professional agriculturist as a leader in finding ways and means of relieving and finally overcoming the situation. He mentioned the outstanding role the technical agriculturists of Italy were playing in the agricultural renaissance of their country—a fact which we had ample occasion to confirm later on—and expressed the hope that the conference would be successful in creating an organization which would effectively further the interests of the professional agriculturists and with them, those of the farmers all over the world. The delegates of the different countries then replied very briefly in their own languages, of which there were fifteen. Fortunately this babel was reduced for the official proceedings which followed to the use of Italian, French, English and German, which was quite sufficient to make progress difficult in spite of the very efficient interpreter.

Papers were presented by Dr. Franco Angelini on the aims of the International Federation of Technical Agriculturists, by Dr. E. Fileni on the international recognition of academic titles, and on the social function of agriculture ("Ruralizing the world") Prof. B. Maymone spoke on the organization of college and university studies in agriculture. The rest of the time was given over to business sessions, round table discussions and excursions, and whatever moments were left were made most enjoyable by the splendid hospitality of the Italian Department of Agriculture, the Department of External Affairs, the International Institute of Agriculture, the Italian Federation of International Workers and, last but not least, of our Italian sister organization.

It would be impossible to report in detail the deliberations of the business sessions, or the papers cited above which will all be made available in print. It will be sufficient for the purpose of this report if mention is made of some of the more serious difficulties which had to be overcome in drafting statutes acceptable to all, and of the aims of the federation as laid down in these statutes.

A rather delicate question proved to be the one as to who should be admitted to membership. In some European countries there are a great many educational institutes which range between the agricultural schools and the colleges and universities, so that the term "technical agriculturist" is

not as easily defined as on the North American continent. It was finally decided that membership should be limited to professional men who possess degrees of strictly academic standing. This renders the situation of the Canadian Society of Technical Agriculturists, as requiring the same qualifications, quite clear with regard to the International Federation.

Lengthy discussions were also devoted to the question as to whether individuals not adhering to any national association should be admitted to membership. Recognizing that it would be impossible for the Secretary General or even a membership committee to pass judgement on the qualifications of applicants from so many countries with educational institutions of varied standing it was decided that membership should be collective in all cases, and consequently the name of the organisation was changed to International Federation of Associations of Technical Agriculturists.

Other decisions of interest were:

The Federation works in close coöperation with the International Institute of Agriculture in Rome, thus benefitting from its facilities, and, if occasion arises, also with the International Labour Bureau in Geneva. Its head-offices are located in Rome. It is financed through an annual contribution of one gold lira per member of the adhering associations (about 23 cents). Its chief aims are:

To take care of the interests of the profession in the international, and if called upon also, in the national spheres.

To facilitate post-graduate studies and other means of advancing the knowledge and qualifications of its members. (Organisation of excursions, courses and congresses).

To establish, in every adhering country, an information service where transient members may find assistance and advice of technical and general nature. It will also be endeavoured to obtain special rates from transportation companies for the members wherever possible.

To establish scholarships and bursaries and to facilitate the exchange of workers and students from one country to another.

These points cover, in a brief outline, the scope of work of the new organisation. It may be added that none of the delegates came as plenipotentiaries from their respective organisations. The federation was therefore founded and the adhesion of all societies represented was declared only subject to the approval through the executives or general assemblies, as the case may be. There seems little doubt, however, that the federation is here to stay. If it succeeds in living up to the tasks it has set itself it will be performing a worth while service to our profession and agriculture at large.

The first president of the Federation, H. E. Baron G. Acerbo, Minister of Agriculture of Italy and himself a graduate in agriculture, was elected by acclamation. Dr. Franco Angelini was chosen as Secretary-General. In addition to the vice-presidents there is an executive of six members which will guide the destinies of the federation.

## Notes and News

A. S. Ward (Alberta '21) has joined the research staff in the Fertilizer Division of the Consolidated Mining and Smelting Company of Trail, B.C.

G. A. Ewart (Manitoba '14), Commissioner, Board of Trade, Regina, has changed his address to 2345 Rae St., Regina.

J. C. Noble (Manitoba '11) has been appointed Senior Inspector of the Dominion Seed Branch at Saskatoon, and is located in the Federal Building.

A. Morin (Laval '17), formerly at the Provincial Dairy School, has been appointed Live Stock Commissioner for the Province of Quebec.

G. H. Jones (Manitoba '13) who for the past eight years has been manager of the Canadian Pacific Railway supply farm at Strathmore, Alta., has accepted the position of Zone Manager for the Canadian Finance Corporation with headquarters at Portage la Prairie, Man.

E. Braun (Manitoba '28) who spent the winter on graduate work at the University Farm, St. Paul, Minn., returned recently to take over his work again at the Dominion Experimental Station, Morden, Man.

G. A. Ledingham (Saskatchewan '27) will be located at Northport, Washington, in connection with the Trail Smelter Fumes Investigation for the summer.

J. M. Armstrong (Saskatchewan '29) has received a National Research Council Studentship to work under Dr. C. L. Huskins, McGill University. His work will be on some phase of plant cytology continuing the studies started under Dr. W. P. Thompson, University of Saskatchewan.

M. H. Peech (Saskatchewan '30) has been awarded a research fellowship tenable for a period of two years at the Ohio State University. Since graduation Mr. Peech has been employed as a soil chemist under the direction of Prof. A. H. Joel, University of Saskatchewan.

R. C. Russell (Saskatchewan '24), Plant Pathologist, has returned to his duties at the Dominion Laboratory of Plant Pathology, Saskatoon, after a year's study at the University of Toronto towards his Ph.D. degree.

A. McPherson (Manitoba '20) Seed Inspector, formerly stationed at the Dominion Seed Laboratory, Saskatoon, has been transferred to the Regina Laboratory. L. Bell (Saskatchewan '30), formerly instructor in the Field Husbandry Department, University of Saskatchewan, is now with the Dominion Seed Laboratory at Saskatoon.

The Dominion Seed Laboratory at Saskatoon is now located in their new quarters in the recently completed Federal Building. The office and laboratory accommodations are excellent. Mr. N. Young (Manitoba '24) is the District Inspector with Mr. T. W. L. Burke (Saskatchewan '23) Analyst in charge of the seed testing laboratory.

Andrew Stewart of the Manitoba Agricultural College has won the Royal Bank of Canada economics fellowship competition for 1930-31. The prize was worth $1000. and is open to the whole field of economics. Mr. Stewart's prize winning paper was called "The economy of machine production in agriculture," and his winning is a credit to himself and to Dr. R. W. Murchie, Professor of Economics and Sociology at the Manitoba Agricultural College under whom he took his work.

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## Convention Dates:

## O.A.C., Guelph, June 22 - 26, 1931

# THE EXPERIMENTAL MODIFICATION OF HEREDITY IN CROP PLANTS * †

## II. Induced Mutation ‡

L. J. Stadler §

*Agricultural Experiment Station, University of Missouri, and Bureau of Plant Industry, United States Department of Agriculture, Columbia, Mo.* **

Mutation is a transmissible change in the gene. The word is sometimes used in a generic sense for all heritable variations, and those which result from change in the individual gene are then designated by some such term as gene-mutation, transgenation, or genovariation. Mutation in the specific sense, in which it is here used, is synonymous with these terms. Whatever the terminology, the distinction drawn is that between those variations which result directly from a change in the individual gene, and those which result from gross loss, reduplication, or rearrangement of unchanged genes. The geneticist has stressed this distinction because of his conviction that the problem of organic evolution is fundamentally the problem of gene evolution. Variations due to chromosomal irregularities are just as truly heritable variations as those due to mutation, but the phenomena which cause them are not directly concerned in the evolution of the gene.

While the distinction between genic and chromosomal variation has been very useful, it must be remembered that it may be, in specific instances, a rather superficial one. There is no doubt that "qualitative" changes in the gene occur, but this does not mean that all mutations are qualitative changes. A change in the gene may be recognized only by its effects, and it is probable that there are various types of change which may produce the effects characteristic of typical gene mutation. For example, if the absence of a given gene has some recognizable effect on the organism, a disturbance causing the destruction or loss of this gene without incapacitating the chromosome for subsequent normal distribution, would produce a variation inherited in typical Mendelian fashion. The result would be analogous on a reduced scale to sectional deficiency, but the variation would meet every test of typical gene mutation.

The actual basis of distinction, therefore, is the extent of the region concerned, rather than the nature of the change. Deficiency involving a chain of genes may be detected by the use of markers allelomorphic to the deficient genes, but in plant species the known loci are so few as to make this method applicable only in exceptional cases. In Drosophila, in which relatively short deficiencies may be detected in this way, all deficiencies investigated have been found zygotically lethal or nearly lethal unless "covered" by an

*Lectures before the Canadian Society of Technical Agriculturists, Wolfville, N.S., June 24 and 25, 1930.

†A general account of the results of these experiments to May, 1929, has been published in the Journal of Heredity (8). This should be consulted in connection with the present summary, since unnecessary repetition of material included in the earlier report has been avoided in preparing the lectures for publication.

‡The first part of this communication (1. Induced Chromosomal Irregularities) was published in the May number of this Journal.

§Associate Professor of Field Crops, University of Missouri, and Senior Geneticist, United States Department of Agriculture.

**The experiments reported were supported in part by a grant of funds and equipment by the National Research Council, Committee on Effects of Radiation on Living Organisms.

unaffected homologous section. In other words, the loss of a chain of genes long enough for detection always has involved the loss of something essential to normal development. In plants, the interposition of the gametophyte generation provides a very useful check on the occurrence of deficiencies which might otherwise be considered mutations. Deficiencies identified by genetic or cytological evidence are in all cases found to be lethal to the haploid gametophyte. This is not necessarily true of polyploid species, in which the gametophyte is not strictly haploid, but, so far as I know, there is no recorded case in a diploid plant species of a deficiency transmitted beyond the generation in which it first occurred.

The gametophytic lethal effect is not to be considered an infallible criterion for the detection of deficiencies, for there may be mutant genes which are lethal to the gametophyte, and there may be minor deficiencies which have no lethal effect. But induced variations inherited as if dependent on a gene lethal to the gametophyte are not convincing evidence of induced mutation; since the treatment is known to induce deficiency and since the mode of inheritance of these variaitons is precisely that to be expected of plant characters resulting from deficiency. In investigating the occurrence of induced mutation, therefore, the mutations sought are those which produce visible characters of the sporophyte and have no effect on the viability of the gametophyte. While it is possible that even these may be due to the absence of a gene or genes, there is no more ground for the suspicion in induced mutations of this kind than in typical mutations of spontaneous origin.

## Induced Mutations in Maize

The pollen and embryo treatments previously described produce mutations as well as chromosomal abnormalities. Since mutation also modifies the genetic constitution of the tissue derived from the affected cell, its outward effects may be similar to those of grosser chromosomal irregularities resulting from the same treatment.

Consider, for example, the effects of the treatments applied shortly after fertilization. A genetic change induced at this stage affects the treated plant as a whole. In the case of any homozygous gene, dominant mutation of one allelomorph would modify the phenotype, while recessive mutation would not; either would normally cause segregation of the mutant type in the next generation.

Among the plants grown from the treated embryos, the only ones which show new characters are the defective plants, which are of various types. These are in all cases partially sterile, and none of the defective types has been reproduced in later generations. They may be formally accounted for as the result of dominant mutations which are lethal to the gametophyte, but, since representative instances are clearly shown to be due to deficiencies, there is no ground for assuming that the other cases represent single-gene changes. No new character inherited as a typical Mendelian dominant has appeared among the treated plants.

In selfed progenies of the treated plants, in numerous instances, new characters not present in either parent have segregated as typical Mendelian recessives. The occurrence of the recessive mutations is not correlated with

defectiveness or partial sterility of the treated plants, the large majority occurring in plants which are normal in vigor and fertility. Several of the mutants show linkage with chromosome markers segregating in the same cultures.

Recessive mutations of the dominant genes used as markers, which would affect the treated plant phenotypically, probably have not occurred. In several instances dominant markers have been lost following irradiation, but, since this loss is accompanied by partial sterility and usually by defective development, it is more probable that these cases represent deficiencies which include the marked locus.

Irradiation at other stages yields similar results. Treatments applied to the more advanced embryo or the mature seed induce mutations which affect only a sector of the treated plant. Occasionally these segregate in much reduced ratio in the next generation (the $F_2$ of the linkage cross), but most of them do not appear until the $F_3$. This is a decided disadvantage in the routine determination of linkages, since some of the chromosome markers segregating in the $F_2$ will have become homozygous in the $F_3$.

Plants produced by the use of treated pollen also yield recessive mutants in their selfed progeny. When the mutant gene is linked with a marker gene dominant in the male parent, the linkage is indicated in the $F_2$ in the repulsion phase. The mutations induced by embryo treatment may show linkage in either the coupling or repulsion phase. Irradiation of pollen induces mutation in only the paternal set of chromosomes, while irradiation of the embryo affects both sets, but this disadvantage of pollen treatment is more than balanced by the possibility of applying much heavier doses to the pollen. Treatments which injure a large proportion of the pollen permit the production of well filled ears, since the injured pollen is eliminated before fertilization.

The progenies of irradiated plants have been systematically examined only for mutants recognizable in the seeds or seedlings. About 40 of these have been found, the large majority being seedling mutants. The mutant seed characters included are defectives of various grades, most of them completely inviable. The seedling characters are in almost all cases chlorophyll abnormalities. The most common mutant type is "white seedling," which has occurred 11 times. Other familiar seedling characters which have occurred one or more times are virescent, yellow, pale-yellow, pale-green, yellow-green, fine striped, argentia, and dwarf (figure 1). Linkage relations are indicated for several of the mutants by the $F_2$ ratios in cultures which include chromosome markers. Two of the white seedlings and a yellow-green appear to be linked with *C-Wx*, a virescent and a pale-yellow with *Pr*, a yellow-green with *Su*, a white with *R*, etc. The possible allelomorphism of the induced mutations with previously known mutants of similar appearance and linkage relations has not yet been checked.

The elaboration of the chromosome map of maize by the use of radiation-induced mutation will require the production and genetic localization of mutations on an extensive scale. Only a small proportion of the mutants are "good characters." The most useful mutants are those which are clearly recognizable in the seeds or seedlings but which are fully viable and

Figure 1. Maize mutant "dwarf".

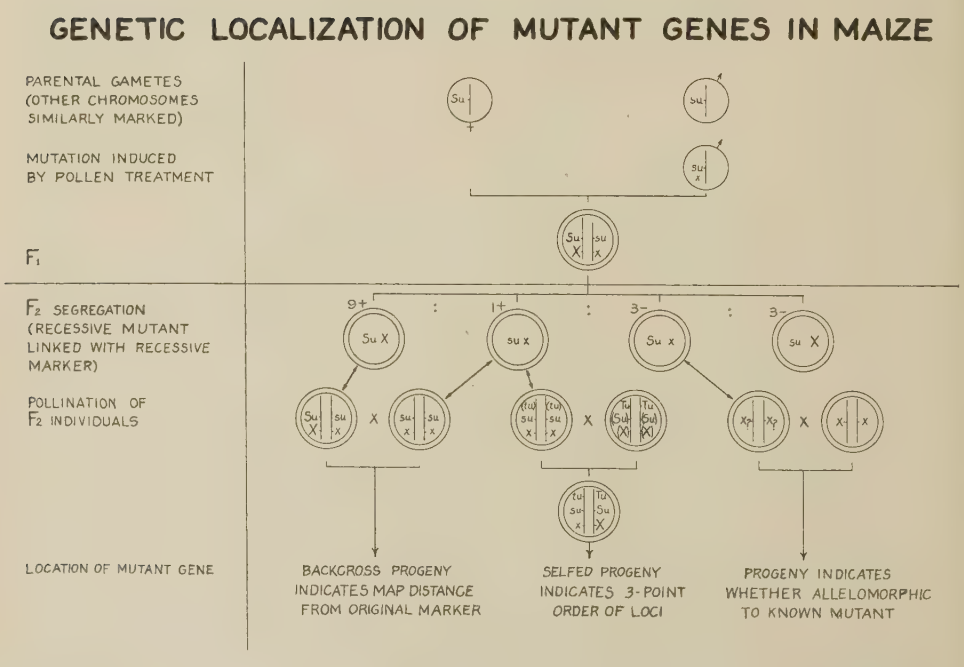

GENETIC LOCALIZATION OF MUTANT GENES IN MAIZE
PARENTAL GAMETES (OTHER CHROMOSOMES SIMILARLY MARKED)
MUTATION INDUCED BY POLLEN TREATMENT
F1
F2 SEGREGATION (RECESSIVE MUTANT LINKED WITH RECESSIVE MARKER)
POLLINATION OF F2 INDIVIDUALS
LOCATION OF MUTANT GENE
9+
1+
3-
3-
BACKCROSS PROGENY INDICATES MAP DISTANCE FROM ORIGINAL MARKER
SELFED PROGENY INDICATES 3-POINT ORDER OF LOCI
PROGENY INDICATES WHETHER ALLELOMORPHIC TO KNOWN MUTANT

Figure 2. Technique for routine mapping of new mutants in maize. (Explanation in text).

fertile. Most of the seedling mutants with conspicuous chlorophyll abnormalities are unable to survive the seedling stage.

The method now used for routine mapping of new mutants in maize is illustrated in figure 2. Each chromosome is marked by at least one gene, endosperm and seedling markers being used as much as possible. The recessive chromosome markers are combined in the male parent and the treatment is applied to the pollen, so that linkage indications in the $F_2$ will occur in the coupling series. This is advantageous because $F_2$ progenies of a given size indicate linkage in the coupling series over longer map distances than in the repulsion series. In order to increase the total dose applied to the pollen, the tassels are treated repeatedly during the period between meiosis and pollen shedding. In some cases additional treatments are applied to the ears before and after pollination, foregoing the advantages of coupling in order to produce as many mutations as possible in the ears to be examined. The $F_1$ plants are selfed. During the winter season following, the selfed ears are examined for seed character mutants, and a sample of 25 seeds from each ear is planted and examined for seedling character mutants. The ears which segregate mutants of possible value are separated for the endosperm characters used as chromosome markers, a remnant of each class is reserved, and the remainder of the seed is planted to indicate the linkage group to which the mutant belongs. If, for example, the mutant is a virescent apparently linked with *Su*, a remnant of *Su* and *su* seed is planted in the field, and a *su v* plant is crossed with several *Su V* plants. Some of the latter will be *Su su V v*, and the crosses with these will give back-cross ratios indicating the map distances from *su* to *v*. A *su v* plant is also out-crossed with a stock carrying another marker of the *Su* chromosome, preferably a dominant. The $F_2$ progeny of this cross will show the 3-point order of the genes. If a mutant gene of similar effect is already known in the same chromosome, a test of allelomorphism is also made. For example, in the culture illustrated, a virescent plant would be crossed with a stock of $v_8$, a virescent known to be linked with *su*. If the new mutant is allelomorphic to the old, the $F_1$ of this cross will be virescent.

## Quantitative Studies of Mutation Frequency in Barley

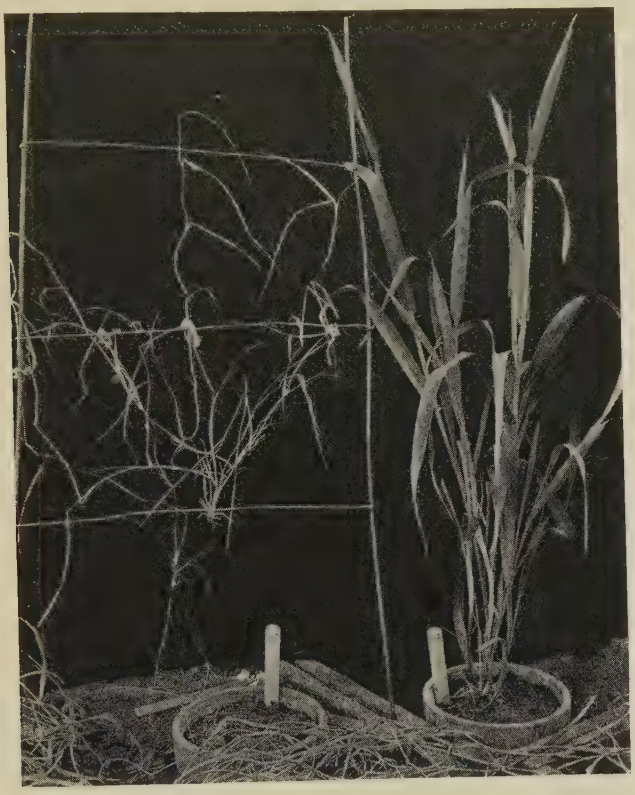
Although maize has distinct advantages over other plants for the genetic analysis of the induced mutations, it is not ideal material for quantitative studies of mutation frequency. For experiments requiring the production of mutations in large numbers and not requiring genetic analysis of the individual mutations, barley is much more favorable material. Its chief advantages over maize are (1) it is naturally self-fertilized, while maize requires hand-pollination, (2) about 25 times as many plants are produced on an equal area, and (3) each plant produces several inflorescences separately affected by treatment of the mature seed. In barley, mutations induced by seed treatment regularly segregate in the next generation, because of self-fertilization within the flowers in the affected sector. In maize similarly treated, few of the induced mutations segregate in the selfed progeny of the treated plant. A sector including part of the ear may not extend into the tassel, and if it does so, the flowers of the affected portion of the ear will be pollinated by a mixture of pollen from affected and unaffected portions of the tassel.

The technic followed in the experiments with barley has previously been described (*5, 8*). In brief, it consists in the irradiation of the seed, followed by examination for mutation in three heads which trace to separate primordia in the treated embryo. In the quantitative experiments seedling mutations only are determined, and only distinct and conspicuous mutant types are counted in determining the mutation rates. The mutant segregates in a single head progeny (usually appearing in less than one-fourth of the seedlings), and the other heads of the same plant are unaffected. In almost all cases, some of the normal plants of the segregating head progeny segregate the same mutant as a typical recessive in the next generation. Partial sterility occurs as an effect of treatment, as in maize, and results in sterility of one-half or more of the spikelets, scattered at random in the affected head or sector. Mutations are no more frequent in partially sterile heads than in others.

Comparative mutation rates are computed as number of mutations found per hundred head progenies tested. If the germ cells of each head were derived from a single cell of the mature embryo, this would represent the rate of mutation in the cells irradiated. But it is evident from visibly sectorial plants that the sector affected by a single mutation varies widely in size, and seldom includes an entire head. On the assumption that the average proportion of mutants within the heterozygous sector is 25%, the average size of the sectors in which mutations are detected may be determined from the totalled segregation ratios. On this basis, the mutant sectors appear to include on the average about half of the spikelets of the head, and their average size does not differ materially in the main heads and tiller heads used. This does not determine precisely the average number of treated cells represented by each head progeny, and therefore does not provide a very satisfactory basis for converting the observed frequencies to mutation rates in terms of cells irradiated. The mutation rates in terms of head progenies tested, while without significance as absolute rates, are strictly comparable for seeds of the same kind, irradiated at the same stage of development.

About 800 seedling mutations in barley have been recorded in these experiments. The general description previously published (*8*), which was based on about 300 of these, will serve fairly well as a description of the larger group. Although more than 95% of the mutations affect chlorophyll characters, the remainder include a wide range of morphological abnormalities. Some of these are pictured in figures 3, 4, and 5. Several new mutant chlorophyll characters also have been found, particularly among the less conspicuous mutants not counted in the quantitative experiments. Some of these are viable and well suited to genetic use.

The most striking feature of the barley mutations is the extreme rarity of dominant mutations. The segregation ratio in the head progeny in which the mutant first appears is not a positive test of dominance, since (1) a dominant segregating in a small sector may affect only a small proportion of the entire head progeny, and (2) two recessives of similar phenotype segregating in a single large sector may result in a high ratio. The segregation of two mutants of different phenotype in the same head progeny has occurred in several instances, and since indistinguishable "whites" make up so large a



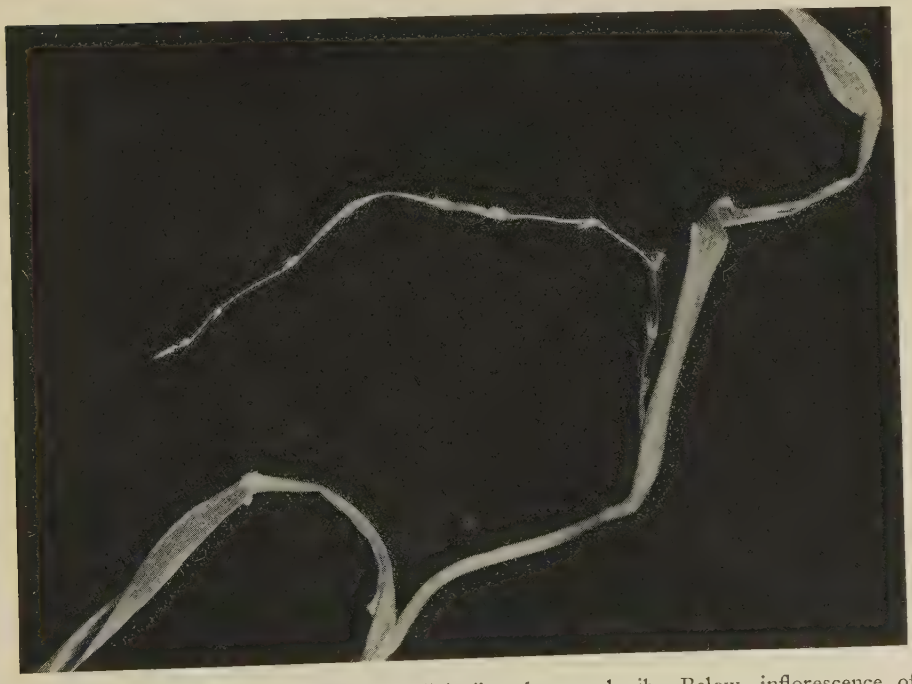


Figure 3. Above, barley mutant "vine" and normal sib. Below, inflorescence of mutant "vine", enlarged.

Figure 4. Barley mutant "twirled" (left).

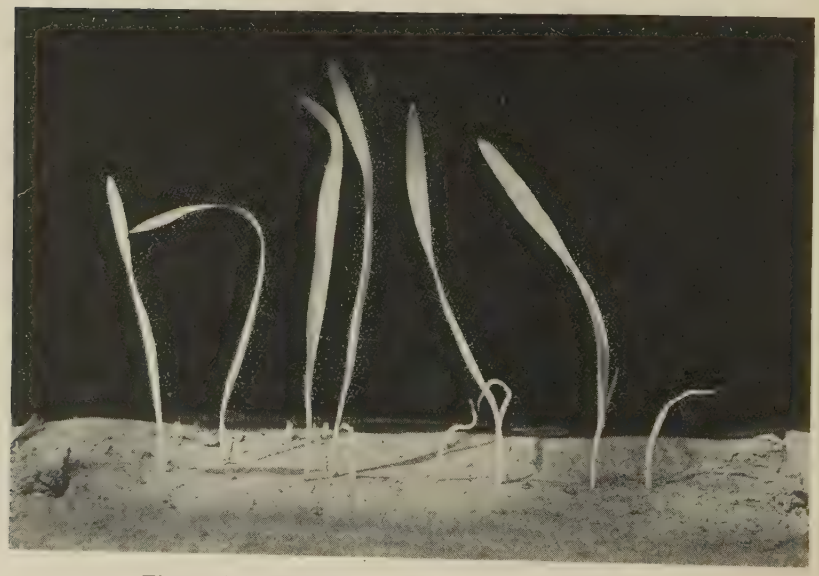


Figure 5. Barley mutant "twisted" and normal sibs.

proportion of the mutations, the occasional segregation of two whites in the same head is to be expected. Such cases are readily distinguished from dominant mutations by the segregation of recessive white from the normal sibs in the next generation. The advanced generation test has now been completed for about 150 mutations (including a few which originally appeared in approximately 50% of a head progeny) and none of these give any indication of dominance. In all cases the heterozygote is phenotypically indistinguishable from the homozygous normal.

A much more extensive test of the frequency of dominant mutation is the occurrence of mutant sectors in the plants grown from the treated seeds. Induced dominant mutations should show their effects not only in the progeny of the heterozygous sector, but in the sector itself. All of the treated plants were closely examined for heterozygous sectors showing the effect of mutation. Mutations with even a very slight dominant effect, in which the heterozygote might not be distinguishable from the homozygous normal when compared in separate plants, should be detected by this examination, for the mutant and non-mutant tissue are side by side in the same plant. In addition to the sectors in which recessive mutation may be detected by means of the progeny tests, the sectors which do not reach the head, and which therefore are not represented by the progeny tests, are included in the examination for dominant effects. These sectors, however, should not be included in estimating the relative frequency of dominant and recessive mutation, since recessive mutations affecting them would not be detected.

The treated plants examined for sectors showing dominant mutation include not only those of 1928 and 1929, in the progeny of which some 700 recessive mutations have been found, but also the large planting of the present season, in which the frequency of recessive mutation has not yet been determined. From the evidence on mutation frequency already obtained, this planting may be expected to yield considerably more than 1000 recessive mutations. The total number of recessive mutations, exclusive of those for morphological characters which might not be detected in sectorial chimeras, was certainly more than 1600 in the plants examined for dominant mutations. Among these plants only 4 have shown sectorial variations affecting part of a head. Chimeras of this sort, though they may result from dominant mutation, may result also from various other genetic causes. Of the four sectorial plants, three occurred in the planting of this season, and their genetic nature is not yet known. The other plant has been tested and found not to be the result of dominant mutation. It is evident that dominant mutation is exceedingly rare in this material and it is possible that no dominant mutations have occurred.

Mutations of the same general type are induced in barley by electromagnetic radiations throughout the available X-ray range. Various radiations have been used, the extremes being the gamma rays of radium (wave lengths chiefly from .009 to .05 Ångstrom units) and "grenz-rays" (*1*) or ultra-soft X-rays generated at 7 K.V.P. (wave lengths chiefly from 2 to 4 Ångstrom units). Mutations are induced similarly by beta rays of radiothorium and by cathode rays. For a given radiation applied to seeds of a given physiological state, the mutation rate is proportional to intensity, within the limits of sampling error.

*Physiological variation in mutability.*—Is each gene characterized by a constant and definite degree of mutability, or does it, under changing physiological conditions, vary in susceptibility to transmutation? It is not practicable to investigate this question in the case of individual genes, because of their low mutation rates, but it is possible to determine the total frequency of mutation for the same group of genes irradiated under different conditions or in different stages of plant development.

The problem is complicated by the possibility of differential survival and multiplication of mutated and unmutated cells. There is no doubt that there are significant differences in the frequency of the genetic changes detected following treatment at different stages. To cite an extreme example, induced chromosomal deficiencies are found in large numbers after irradiation of mature pollen, but their frequency is much lower after earlier treatments of the tassel. This may be due to increased susceptibility to chromosome breakage in the mature gametophyte, but it is probably due at least in part to the elimination or the competitive inefficiency of deficient cells or their cell-progeny when the deficiency is induced in the earlier stages. The differential development resulting from mutation would probably be less than that from deficiency, but nevertheless a difference in the observed frequency of mutations induced at these two stages would be inconclusive because of this possibility. Similarly, differences in the observed effects of treatments applied to male and female germ cells or their primordia are unconvincing, because the conditions determining survival are not comparable.

The most favorable material for this comparison is afforded by the treatments of dormant and germinating seeds. Here an extreme physiological difference is available in embryos differing in stage of development only by the effects of a few hours' growth. Since the mutations to be compared are wholly recessive, and are induced in the diploid sporophyte, they are unlikely to affect the rate of cell-multiplication; but if they do so, the plants compared should be affected similarly. If the slightly advanced stage of development of the germinating seeds has any effect on the observed mutation frequency (through an increase in the number of cells in which detectable mutations may occur), it should be made evident by a proportionate decrease in the size of the sectors affected and therefore in the proportion of mutants in the segregating head progenies.

The frequency of mutation per unit of radiation intensity is regularly much higher in seeds treated while germinating than in seeds treated while dormant (*6*). The extent of this difference varies somewhat depending on the conditions provided for the germinating seeds, the mutation rate in dormant seeds being practically constant in all experiments. Under the standard conditions of germination which we have used most frequently, the mutation rate is about 8 times that found in dormant seeds. There is a corresponding difference in the killing effect of radiation, the dormant seeds tolerating a dose 15 - 20 times as great as that tolerated by the germinating seeds. In this technic the seeds are steeped 6 hours in water at 27° and aerated on moist blotting paper in covered dishes for 18 hours at 27°. If the treatment is withheld until 25 hours after the beginning of aeration, the mutation rate and killing dose are not appreciably changed. Under another set of conditions used in several experiments (14 hours steeping and 5 hours aeration)

there is somewhat less increase in the mutation rate and decrease in tolerance. The average mutant ratio in segregating head progenies is practically the same in both cases as in the trials with dormant seed.

The course of changing mutability and tolerance between the level typical for dormant seed and that for germinating seed may be traced by applying the treatment at various stages during the germinating process. Preliminary experiments indicate that mutability lags behind tolerance in its response to advancing germination. Tolerance decreases during a steeping period of 14 hours to about half that of dormant seed, and is approximately halved again by the first half-hour of aeration, but its further decrease during the next 4½ hours of aeration is less marked. Mutability increases slightly during the steeping period and the first half hour of aeration but makes its chief increase in later stages of aeration.

*Relation to temperature.*—Previous trials (*6, 8*) have clearly shown that there is no pronounced effect of temperature on the rate of induced mutation, such as might be expected if the rate is limited by some process with a temperature coefficient of the order commonly found for biological reactions. In these experiments, in which both dormant and germinating seeds were used, temperatures of 10° to 50°C. were applied during irradiation and for a brief preparatory period.

In the treatment of dormant seeds much lower temperatures may be used without injury to the viability of the seed. Since dormant seeds are so much more resistant to injury by irradiation than are germinating seeds, it seems possible that further resistance might be gained by the application of extreme low temperature. It was found that seeds imbedded in solid carbon dioxide (temperature of sublimation -80° C) would tolerate radiation intensities about ⅔ higher than those tolerated by dormant seeds at ordinary temperatures (figure 6). Mutations were induced by irradiation at the low temperature at a rate per *r* unit about ⅓ lower than that in the control. The difference in mutation rate was only about twice as great as its probable error, and it is therefore not improbable that mutability is unaffected even at this low temperature.

Germinating seeds were irradiated in intermittent exposures at 30-minute intervals through a period of 7½ hours. Temperatures of 7° to 37° throughout this period were without appreciable effect on the mutation rate.

Although temperature during the period of irradiation has little or no effect on mutation, the possibility remains that mutation frequency may be affected by temperature in the period following treatment, during which a series of reactions initiated by irradiation may occur. With dormant seed, temperatures ranging from -80° C to 38° were applied during the 24-hour period following treatment, and in another series temperatures of 5° to 38° were applied during a period of several weeks after treatment. In both trials the mutation rate was unaffected. With germinating seeds temperatures of 7° to 37°, applied for a period of 24 hours following treatment, also had no effect on mutation rate. It is interesting to note that although mutation rate increases definitely with advancing stages of germination, it is apparently unaffected by the heightened metabolism which results from increased temperature after germination activity is established.

Figure 6. Effect of extreme low temperatures on X-ray tolerance. Barley seedlings 12 days after planting. Left, control. Center, dormant seeds irradiated in solid carbon dioxide (-80°C.). Right, dormant seeds irradiated similarly at 23°C. The maximum intensity tolerated at -80° is about ⅔ higher than at 23°.

## Mutation in Polyploid Species

In many genera of plants the chromosome numbers of related species form an arithmetical series. *Hordeum vulgare,* the common barley used in these experiments, has 7 pairs of chromosomes; other species of Hordeum have 14 or 21 pairs. In Avena and Triticum (the genera which include common oats and wheat) the same series of chromosome numbers occurs, though in these cases the most commonly cultivated species have the highest chromosome number of the series, instead of the lowest as in Hordeum. Many similar series are found in various plant families. In some cases the series is more extensive, as in Thalictrum (7, 14, 21, 28, 35, 42), Draba (8, 16, 24, 32, 40), and Chrysanthemum (9, 18, 27, 36, 45). Presumably the higher chromosome numbers have resulted from successive reduplication or addition of chromosome groups of the basic number. The species whose chromosome numbers are multiples of the basic number are called polyploid species, but the use of this term does not imply that the chromosome groups combined are necessarily identical.

Many of the most important crop plant species are polyploid, including, in addition to oats and wheat, such important crop plants as cotton, tobacco, potatoes, and alfalfa. Any program for the utilization of radiation-induced mutation in the improvement of these crops must take into account the effect of polyploidy on the frequency of induced mutation.

To illustrate this effect consider a hypothetical species of Hordeum with 14 pairs of chromosomes, made up of duplicate groups of chromosomes identical with those of *Hordeum vulgare*. Assume that each gene in this polyploid mutates under irradiation at the same rate as in *H. vulgare*.

Although twice as many mutations would occur, probably very few mutations would be detected. A recessive mutation of a gene in one group would not show its effect because of the unmutated duplicate gene in the other. Indicating duplicate pairs of genes in the two groups as $A_1A_1$ and $A_2A_2$, and indicating a mutated gene by parentheses, the original constitution of the polyploid would be $A_1\ A_1\ A_2\ A_2$, and the homozygous mutant segregate $A_1\ A_1\ (A_2)\ (A_2)$. These two types may be expected to differ phenotypically to about the same extent as the diploid types AA and A(A), in which the same genes are present in the same proportion. In other words, the mutant type probably would be distinguishable when the mutation is dominant or partially dominant, but not when the mutation is wholly recessive. As previously stated, practically all of the mutations induced in barley by irradiation are completely recessive. These mutations would not be expected to show their effects in the presence of an unmutated duplicate gene. Coincidental mutation of the same gene in both groups would lead to the segregation of the mutant type in digenic ratio, but this would probably be so rare as to be negligible. Coincidental mutation of allelomorphs has never been found in the extensive experiments with diploid barley.

But the chromosome complement of existing polyploid species is not made up of duplicate groups of chromosomes. It is almost certain, because of previous mutations or of hybrid origin, to include some dominant genes which are not reduplicated. Recessive mutation of these genes should be as readily detected as recessive mutation in the diploid species. Species with a double chromosome complement, therefore, might be expected to yield some detectable mutations. Species with a triple complement would be likely to have a smaller number of dominant genes which are present in only one group of chromosomes, and therefore a lower apparent mutation rate.

The frequency of visible seedling mutations in common oats and wheat irradiated under the conditions previously described is far below that found in barley similarly treated (7). Cultivated varieties of oats and wheat belonging to the species with 21 pairs of chromosomes yielded only one seedling mutation, under treatments which, if applied to barley on the same scale, would have yielded more than 100. On the other hand, species of Avena and Triticum with 7 pairs of chromosomes yielded seedling mutations at rates comparable to that of barley. In durum wheat, an extensively cultivated species of Triticum with 14 pairs of chromosomes, the frequency of seedling mutations was intermediate between that found in the 7-chromosome species and the 21-chromosome species of the same genus. The fraction of the head included in the sector affected by a single mutation apparently does not differ greatly in the species in which mutations are found. The mutant types found are in general similar to those found in barley, though they occur in somewhat different proportions.

The great decrease in mutation frequency in the economically valuable species with the triple chromosome number may not be entirely a disadvantage in possible practical applications of induced mutation. If the treatment is used to induce a change in a specific character known to be dependent on a single dominant gene, the chance for the desired mutation is presumably as good in the polyploid species as in the diploid. For example, suppose that a

wheat variety otherwise highly desirable is susceptible to a certain disease, and that crosses with resistant varieties show this susceptibility to be due to a single dominant gene. If the resistant varieties are otherwise very undesirable, hybridization to add disease resistance to the desirable variety is likely to add also some of the undesirable qualities of the resistant parent. Irradiation of the susceptible variety may induce mutation to the recessive resistance, for if the low mutation rate of polyploid species is due merely to gene reduplication, the single gene for susceptibility is as likely to mutate in the polyploid as in a diploid species. Polyploidy will prevent the appearance of the great number of miscellaneous mutations which would appear in the diploid species, but in this case their absence would be advantageous.

The foregoing discussion is concerned with induced mutation, and does not apply to induced chromosomal irregularities. Variation due to the latter cause would probably be increased rather than decreased by polyploidy, (1) because of the increased number of chromosomes which may be affected, and (2) because of the viability of the genotypes resulting from various chromosomal irregularities which would be lethal in the diploid species. A most important factor determining the genetic effects of chromosomal losses and rearrangements in diploid species is the gametophytic lethal effect of deficiency, which prevents the transmission of deficient sets of genes through the haploid gametophyte generation. But in the polyploid species the gametophyte is not strictly haploid, and it may be expected that some deficiencies will have no gametophytic lethal effect. The reduplication of a chromosome or section also would be expected to have a less pronounced effect in the polyploid than in the diploid species, since the resulting genic unbalance would be less. The cytological investigations of Winge (*10*) and Huskins (*2, 3*) have shown that certain types of "fatuoids" in common oats and "speltoids" in common wheat are characterized by the deficiency or duplication of entire chromosomes, and that both conditions are transmitted through the gametophyte.

We may expect therefore that some of the deficiencies induced in polyploid species, instead of being promptly eliminated as in the diploid species, may result in definite character changes transmitted to later generations. Induced translocations will not necessarily cause partial sterility, and may lead to the establishment of constant races characterized by the absence of a portion of the normal genotype or by the presence of a reduplicated portion. An alteration of this sort, if it does not cause abnormal chromosome distribution or selective survival, may be inherited as a typical Mendelian character.

## Discussion

The visible mutations induced by irradiation are identical in genetic behavior with typical mutations of spontaneous origin. They are fully viable in either haploid or diploid tissue, and show normal Mendelian segregation and linkage relations. Many of the mutant characters are indistinguishable from characters previously found in untreated material.

The extreme rarity (or possibly even complete absence) of induced dominant mutations suggests the possibility that we may be dealing with a special class of mutation. No clear case of dominant mutation has been

found in irradiated plants which have yielded hundreds of typical recessive mutations. The classification of mutations as dominant and recessive is arbitrary when partial dominance is involved; but these mutations appear to be completely recessive, for they have no appreciable effect when heterozygous. This is true also of most of the mutant seedling characters of spontaneous origin in barley and maize.

In this connection it should be noted that the segregation of a large class of variations which would appear as dominant mutations is prevented in diploid species of plants by the circumstance that deficiency is lethal to the gametophyte. It has been shown (*9*) that deficiency is induced with high frequency in the irradiated plants, and that the plants heterozygous for induced deficiencies show various types of abnormality or defective development. If the induced deficiency had no effect on the viability of the gametophyte, functional deficient gametes would be produced by such plants, and the deficiency would be transmitted to the next generation in the ratio of 1 homozygous normal: 2 heterozygous deficient: 1 homozygous deficient. If the deficiency were lethal when homozygous the defect resulting from heterozygous deficiency would appear as a dominant mutation with recessive lethel effect. This is substantially the mode of transmission of deficiency in Drosophila, in which gametic lethals are unknown.

The genetic change frequently induced by irradiation of pollen or young embryos in maize, which results in the development of defective semi- sterile plants, may be designated as a dominant mutation with gametophytic lethal effect, in those cases in which there is no evidence of the loss of linked marker genes or of cytologically detectable deficiency. A change in a gene might produce such effects, and in these instances it is impossible to prove that the causal change was not of this nature. If these cases are considered dominant mutations the questions arises: Why are dominant mutations invariably lethal, while recessive mutations are viable in hundreds of instances? But it is improbable that these dominant variations are due to a change in a single gene. Wholly analogous cases in which genetic or cytological evidence is available are clearly shown to be due to deficiency, and it is probable that the cases in which this evidence is not available have a similar basis.

An obvious possibility is that the recessive mutations also are deficiencies. To account for the induced mutations on this basis it is necessary only to assume that some of the induced deficiencies, which are so slight as to have no appreciable effect when heterozygous, may have no lethal effect when homozygous or haploid. These might be losses of single genes or of short sections. To assume that all deficiencies are lethal is to assume that every gene is essential to life. There is no ground for this assumption. It is reasonable to suppose that deficiencies below the lethal level occur, and it is not improbable that some of these may have phenotypic effects which are inherited as recessive mutations. Although it is highly improbable that gene mutation in general is a mere matter of presence and absence, it is possible that the induced mutations are largely or wholly of this nature. But there is no more reason at present to ascribe the induced mutations to gene-loss than to any one of various other types of change which might result from radiation.

Whatever their physical nature, it is probable that spontaneous mutations of the same genes have a similar basis.

There are probably various types of gene mutation, distinct in the physical nature of the causal change, but indistinguishable in the mode of transmission of the mutant character. This fact is generally recognized, but, in speculating on the nature of the gene or the mode of gene evolution, we are prone to overlook its implications. There is no doubt that mutation is induced by radiation, but it is possible that only certain types of mutation are affected. All of the evidence showing increase of mutation frequency is derived from comparisons of the total mutation rate. A 100-fold increase in the total rate may mean that mutations in general are increased 100-fold; but it may mean rather that mutations of a type comprising say 10 per cent of the total are increased 1000-fold, while other mutations are unaffected. There is as yet no positive assurance that the types of mutations involved in gene evolution are affected by radiation.

It is desirable therefore to determine the effect of radiation on the frequency of specific gene mutations, in order to discover whether different types of mutation are differently affected. Unfortunately this is a very laborious process if representative mutations are to be investigated, for in general the natural frequency of mutation of the individual gene is very low. Our present knowledge of the natural mutation rates of specific genes is derived from the study of exceptional mutations which were chosen for investigation chiefly because of their known high frequency. What is needed is a comparison of the mutation rate with and without irradiation in a number of genes which are typical in genetic behavior but unselected as to mutability. Since a significant comparison would require the detection of a considerable number of mutations of each gene, the genetic testing of an enormous number of gametes would be necessary in the case of genes of normally low mutation rate.

Maize offers exceptionally favorable material for the determination of mutation frequency, and we have attempted during the past several years to determine the natural mutation rates for several genes unselected as to mutability. A preliminary trial was made in 1929 to determine the effect of X-ray treatment on the frequency of mutation of 4 of these genes. The number of gametes tested for mutation was large enough to yield a conclusive result only for the gene with the highest normal mutation rate. The mutation rate of this gene was unaffected by irradiation. The experiment is being repeated this year on a scale which should yield conclusive results for the other 3 genes.*

It would be a great mistake to transfer the study of gene variation entirely to the field of induced mutation. The use of radiation greatly facilitates the experimental study of mutation, and enables us to investigate certain phases of the problem which would otherwise be beyond our reach. But the assumption that induced mutation differs from natural mutation only in frequency of occurrence must be clearly recognized as an assumption. This assumption is fundamental in both the theoretical and the practical application of induced mutation. Intensive study of natural mutation as well as induced mutation will be needed to establish its validity.

* The severe drought of 1930 reduced the yield in this experiment to even less than that of the preliminary experiment of 1929. The combined results of the two seasons have been reported (abstract in Anat. Rec., 47: 381. 1930).

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## PLANT BREEDING ABSTRACTS

The Imperial Bureau of Plant Genetics has begun to issue a publication entitled "Plant Breeding Abstracts" in which all the more important current publications dealing with plant breeding and the genetics of crop plants are listed. The references are classified according to subject and each reference is followed by an abstract indicating the subject matter of the paper and the results obtained. The papers are divided into two halves, those published in the British Empire and those published in foreign countries. Papers written in foreign languages are usually abstracted somewhat more fully than papers in English.

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# THE FORMATION OF THE HEN'S EGG *

## Parts II. and III.†

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[Received for publication January 25, 1931]

## II. Determination of the Shape of the Egg

### *a. Review of the literature*

Variation in the shape of eggs is obvious and has been observed and speculated on by many. Szielasko (1905) was one of the first to experiment with a view to finding out how the shape of the egg is determined. It was common opinion long before (Wahlgren, 1871) that the form of the egg is determined in the uterus. Szielasko apparently accepted this view, considering that the secretion of the shell membrane does not give the egg a definite form. He therefore tried to decide between the possibilities, (1) that the uterus acts simply as a mold or (2) that the muscular activity of the uterus gives the egg its form. This was tested by ligating the uterus at the posterior end and injecting fluid into it under pressure from the other end, which caused the uterus to appear egg shaped. Szielasko accordingly concluded that the uterus acts only as a mold, although admitting the possibility that the uterine muscles may take an active part in shaping the egg.

Pearl (1909), while not denying that the uterus may act as an elastic walled mold, states that the shape of the egg is determined by the muscular activity of the walls of the uterus. He bases this conclusion on the gradual changes in the eggs (at first abnormally long and narrow) laid by a pullet. He further states that while the general shape of the egg may be determined before reaching the uterus, "the particular form of each individual egg is determined in the uterus."

Curtis (1914b, p. 322) makes the following statement with regard to the mechanism by which the egg is moved through the oviduct and its effect on the shape of the egg: "From their position and from observed activities of the duct, it seems that the contraction of the circular fibers contract the duct and move the egg forward. The contraction of the longitudinal somewhat spiral fibers expand the duct, diminishing the resistance to the passage and also give the egg the spiral motion. If the resistance is slight, i.e., if the contractions are so timed that the duct ahead of the egg is expanded at the time of the contraction of the circular fibers behind, the egg will be long, narrow and pointed. On the other hand, if the resistance is great the egg will be short and broad." The individuality of the egg is assumed to be due to the coördination of the two sets of muscles and the variations due to differential coördination.

R. and A. Serebrovsky (1926) have expressed somewhat different views from those of Pearl and of Curtis stated above, since they emphasize the importance of the shape as well as the activity of the oviduct. These views are

*Papers from the Department of Genetics, Agricultural Experiment Station, University of Wisconsin, Madison, Wis., No. 116. Published with the approval of the Director of the Station.
†Part I appeared in the May issue of this journal.
‡Associate Professor of Poultry Husbandry.

summarized in the following sentence: "A narrow but feeble oviduct gives a long and egg-shaped egg; a wide, but feeble oviduct gives a short but ellipsodial egg, and finally a wide and energetic oviduct gives a short and egg-shaped egg." This theory is quite similar to that developed by Ryder (1893), who considered that the shape of the egg was the resultant of the resistance of the oviduct in front of the egg and the pressure of the muscles behind.

The theories of Pearl (1909) and Curtis (1914b), while based on observations on the structure of the oviduct and variation in the shape of eggs laid by the same hen and by different hens, are also supported to some extent by the experimental results reported by Pearl and Curtis (1914). They report diminishing the size of the uterus by removing a piece of the wall without perceptibly influencing the size or shape of the eggs subsequently laid.

The measure of shape most commonly used is the length-breadth index employed by Pearl and his co-workers at the Maine Station (Pearl and Surface, 1914, Curtis, 1914b). This is calculated by the formula $\frac{\text{Breadth}}{\text{Length}} \times 100$. R. and A. Serebrovsky (1926) used measurements taken 13.5 mm. from each end of the egg to determine shape. The measurements used by the Serebrovskys take into account differences in the diameter of eggs near the ends, an important point since eggs differ considerably in this respect. These investigators were not able to find any indication of inherited differences in shape but Benjamin (1920) obtained evidence for the inheritance of this character.

### *b. Variation in the Shape of Eggs*

The variability in the shape of eggs has been generally recognized but, except for length and breadth, is difficult to measure and to express numerically. The length-breadth index, while useful as a measure of shape, was not considered adequate for this investigation. For that reason, as stated before, four diameter measurements were taken for each egg. This proved useful for demonstrating certain variations in shape, although the maximum and minimum diameters would have sufficed. Unfortunately there are some variations that can be observed but are difficult or impossible to measure. These variations in shape were recorded and, when possible, typical eggs were photographed.

The measures of shape that will be considered are the length-breadth index and the absolute variation in breadth. These, together with other data on 707 eggs laid by the birds before they were used for experimental purposes, are set forth in table 4. Comparing these with constants for length, breadth, index and weight given by Pearl and Surface (1914), it may be noted that the eggs here studied were slightly longer and narrower, thus giving a slightly lower index. They also weighed slightly less. These differences, while not large, are statistically significant when compared with their probable errors. The variability of these eggs, with the possible exception of breadth, was also slightly greater than of the eggs used by Pearl and Surface but was in the same order. Thus, egg weight was most variable,

then index, length and finally breadth. The greater variability in our eggs is undoubtedly due to the use of a more heterogeneous group of birds than the Maine flock, while the average size is smaller because so many of the eggs were the first few laid. The size is similar to that reported by Curtis (1914b) on the basis of all eggs laid.

It will be seen by reference to table 4 that the difference in breadth was quite small. The mean difference in maximum and minimum breadth was 0.17 millimeters, which is only .41 of 1 percent of the mean breadth. It is of interest to note that none of the eggs measured exactly the same in all four diameters. The range of differences in diameter, which indicates the degree of "flattening" of the egg, was from .02 to 1.67 mm. The frequency distribution is given in table 5. Most of the eggs vary only slightly in diameter, the mean falling in the modal class ranging from .12 to .23 millimeters, while 93.8 percent of the total are included in the first 3 classes, with a difference of .35 mm. or less. The great majority of normal eggs are, therefore, very nearly circular in cross section.

Difference in breadth (maximum and minimum diameter) is not correlated with length, breadth nor egg weight (table 6). The length-breadth index is likewise not correlated with weight of egg, which agrees with other data (Pearl and Surface, 1914). It appears to have been considered by Pearl and his co-workers that variations in shape are due almost exclusively to muscular activity of the walls of the oviduct and especially the uterus. As shown in the following paragraphs, there are other important additional factors which influence the shape of the egg.

### *c. Experimental Modification of Shape*

Some of the results of the various operations performed furnish information with regard to the function of different parts of the oviduct in the determination of shape. These include the following:

1. *Shortening the isthmus.* The results of removing approximately half the isthmus of hen I2742 have already been presented and discussed. In this case there was a definite effect on the shape of the eggs, indicating that the details of its form are not determined alone in and by the uterus but are also influenced by the isthmus.

2. *Narrowing the isthmus.* While operating on a hen (No. 824) for the purpose of temporarily ligating the oviduct, a lengthwise tear approximately 2.5 cm. long was made in the isthmus about the middle , or slightly nearer the uterus than the albumen secreting part. It was closed the following day, after the bird had laid. When she recommenced laying 15 days later her eggs were slightly misshapen and characteristically wrinkled on both ends (figure 4); otherwise most of them were normal in shape for this hen. There is here additional evidence to show that details in the form of the egg are affected by slight alterations in the isthmus. It seems probable that the forcing of the egg through a narrow part of the isthmus before the membrane was completed resulted in a wrinkling of the membrane which remained. If this is the correct explanation, then the shell membrane is not a mere formless covering for the yolk and albumen, but instead has both the general and particular form of the completed egg.

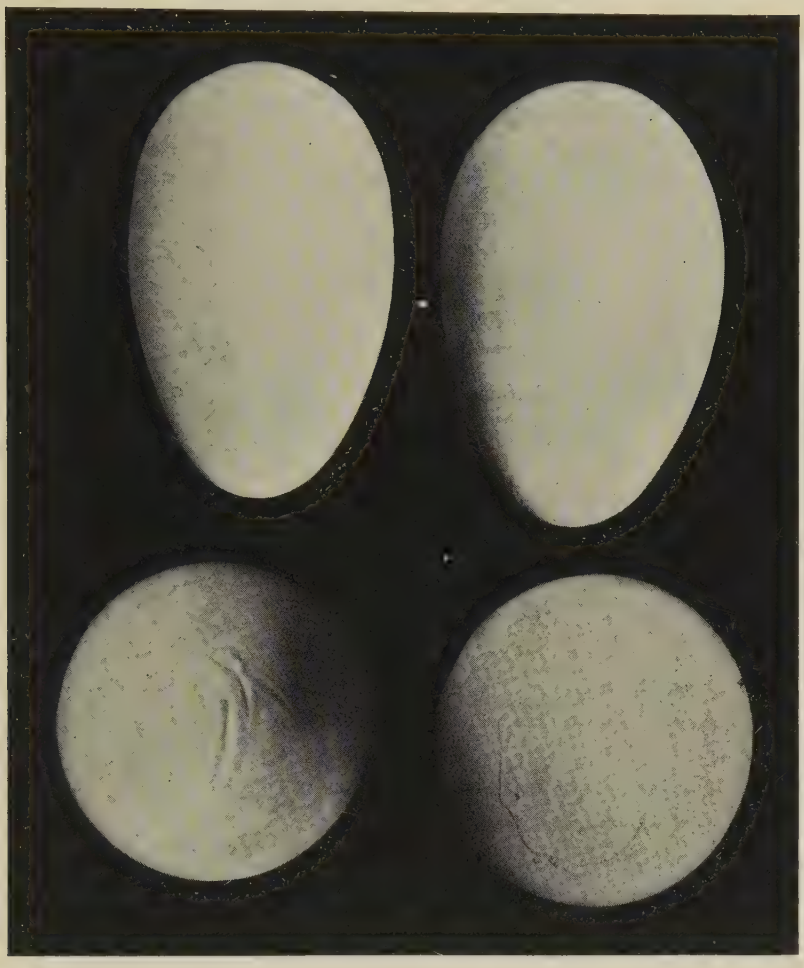

Figure 4. Side and end view of eggs laid by No. 824 showing wrinkling on the ends.

In the side views (figure 4) of two of the eggs laid by No. 824, there are dark colored, irregular-shaped spots on the shell towards the small end. The shell in these places was rough. When these and other eggs from No. 824 with such areas were opened, the shell membrane under them was in each case found to be impregnated with blood. Unlike the wrinkling on the ends, which was shown by all eggs laid after the operation on the isthmus, only a few contained blood on the shell membrane.

3. *Eggs removed from the uterus.* Additional evidence for such a view is furnished by an egg removed from the uterus of 1287, and mentioned above. The egg did not have a hard shell, yet showed the shape characteristic of eggs laid by this bird. Apparently, the characteristic shape of an egg has been determined when the shell membrane is completed, or sooner.

4. *Temporary ligation of the isthmus.* Still further evidence is furnished by No. 812 whose isthmus was temporarily ligated about 3 cm. anter-

ior to the uterus. When the ligature was removed there was a slight swelling around the isthmus where it had been ligated. The eggs laid by this hen before the operation were quite uniform in diameter, the difference between the maximum and minimum diameter being only .12 mm. (table 1). After the operation the average difference in width was .33 mm. or nearly three times as great as before. The difference, in most cases, resulted in one side being straighter than the other (figure 5), although the first few showed a noticeable bending of the egg. Later most of the eggs laid appeared to be normal in shape, but only a few were as uniform in diameter as those laid before the isthmus was temporarily ligated.

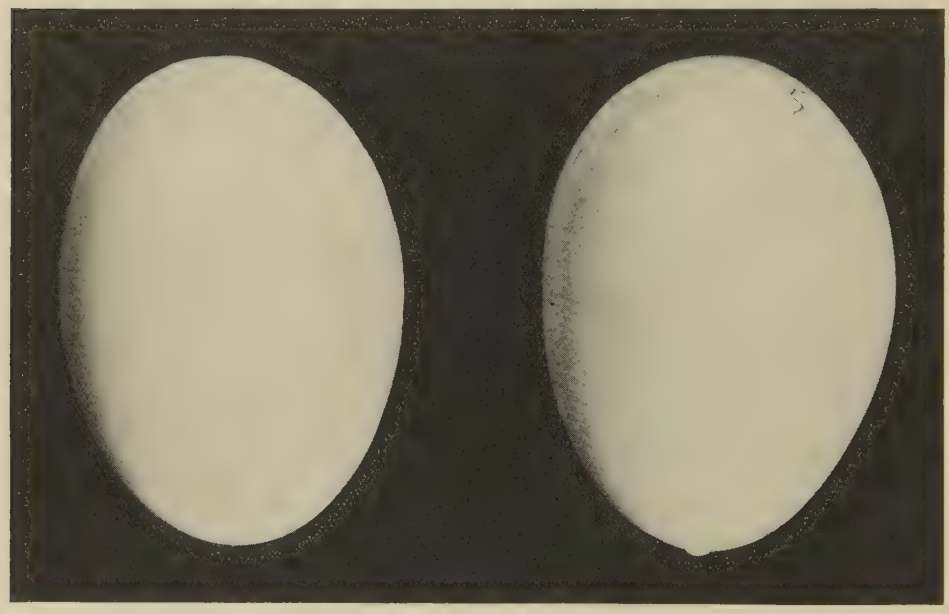

Figure 5. Eggs from No. 812 showing the effect of temporarily ligating the isthmus on the shape of some of the eggs subsequently laid.

Other evidence confirms earlier work showing that the uterus influences the shape of the egg. This evidence is described in the following paragraphs.

5. *Altering the uterus.* Thirteen birds were operated on with the object of altering the uterus and, of the seven that survived, one laid. This bird (No. I2360) was a first generation pullet from a cross of B.P. Rock × W. Leghorn.

When operating on No. I2360, the incision through the skin and body wall was made 5.7 cm. long and in the same place as on I2742. The uterus was next located and a piece 2.5 cm. in length by 1.1 cm. in width was cut out of the ventral side. The wound in the uterus was closed with Lembert sutures. The body wall was first closed with interrupted sutures and then the skin.

This operation was performed on January 14th and the first egg produced after the operation was laid on January 30th, just over two weeks later.

Eight eggs were laid from January 30th to February 15th, when No. I2360 stopped laying. She laid again on February 26th and continued to lay. Sixty of the eggs laid up to and including May 9th were weighed and measured and the weight of the yolk and shell (including shell membrane) was obtained for 34 of these.

The eggs laid by No. I2360 after the operation increased in weight although the average weight of the shells decreased slightly. The weight of the shells varied so irregularly that the decrease in their average weight cannot be attributed to the operation. The eggs laid from January 30th to February 15th and the first few obtained after laying recommenced on February 26th were as deeply tinted as the eggs laid before the operation. Eggs subsequently laid were lighter in color. This variation in color is commonly observed and may be considered normal. There appeared to be no correlation between colour and weight of shell ($r = + .121 \pm .106$) nor between colour and difference in maximum and minimum diameter ($r = -.060 \pm .086$).

This hen was mated and some of her eggs incubated. A number of vigorous chicks were hatched which indicates that her eggs were normal except in shape, which will now be considered.

The egg laid on January 30th was quite similar in outline to those laid before the operation (figure 6a and b). This appeared to be true of the first eight eggs although the maximum diameter of the egg laid on February 15th was .66 millimeters greater than the minimum diameter. This is an unusually great difference in a "normal" shaped egg since only one out of each 78 of the 707 eggs from unoperated hens varied this much in diameter. The average maximum diameter of the 34 eggs from I2360 for which complete data are available was 1.05 mm. greater than the minimum diameter (table 1). The corresponding difference in the maximum and minimum diameter for 60 eggs laid by I2360 up to May 9th was 1.06 mm. Ten of these 60 eggs varied less than .25 mm. in diameter or from .04 to .18 mm. while the other 50 eggs varied from .29 to 3.11 mm. in diameter. The majority of these 60 eggs from I2360 were clearly abnormal in shape being more or less flattened on one side like the egg shown in figure 6c and d.

Partly flattened eggs are occasionally laid by hens that have not been operated upon, and some hens habitually lay such eggs. The cause or causes responsible for the laying of these slightly flattened eggs are not known. For this reason the present case is of special interest since the apparent cause of the abnormal shape (the removal of a longitudinal section from the uterus) is known. The abnormal form of most of the eggs laid after the operation indicates that the actual shape of the uterus is of considerable importance in determining the shape of the egg, but since some of the eggs laid were normal in form, the muscular activity of the walls of the uterus must also influence their shape. In this case the effect of increased muscular activity was apparently to produce normally shaped eggs. Differences in shape, so far as they are determined by the uterus, probably result from variation in the muscular activity of its walls. According to this view a certain amount of muscular activity is necessary for the production of normal shaped eggs.

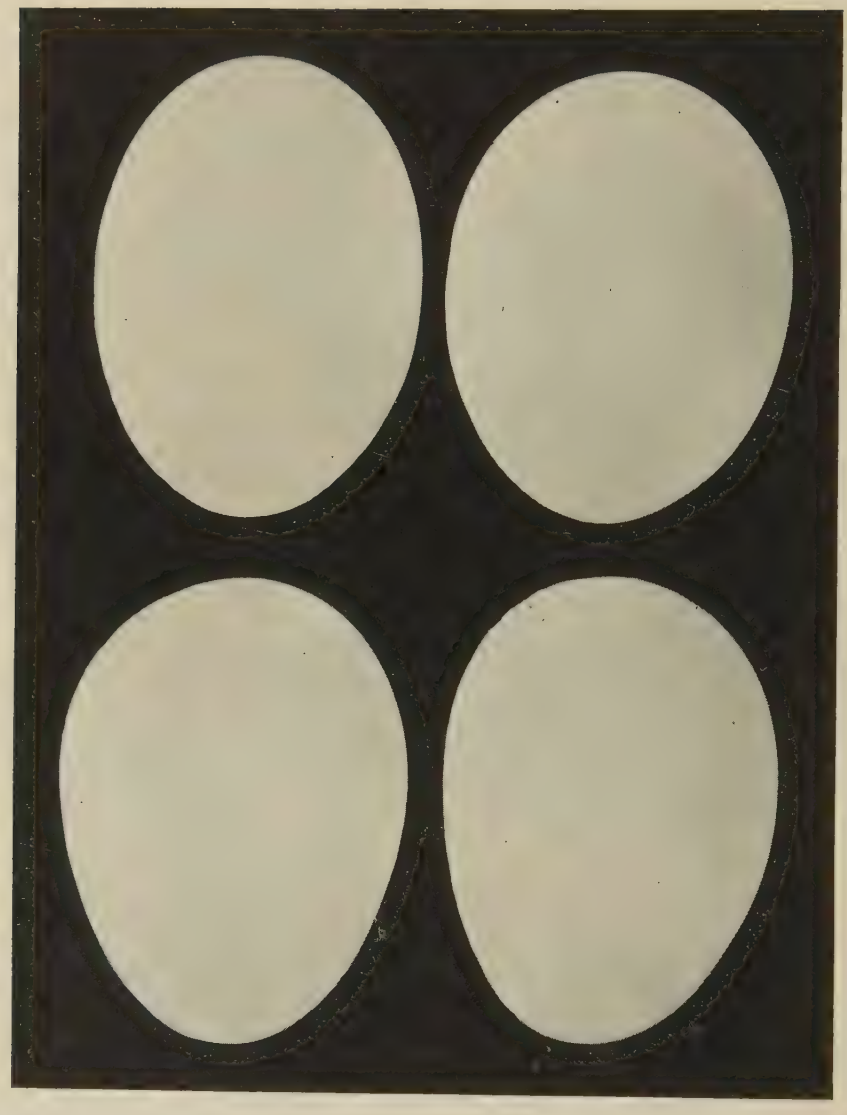

Figure 6. Eggs laid by I2360 (a) Upper left-egg laid before bird was operated on. (b) Upper right-egg of normal shape laid after the operation. (c and d) Lower half shows one of the abnormal-shaped eggs laid after the operation.

6. *Uterus freed from attached ligaments.* There was a possibility that the abnormal shape of the eggs laid by I2360 was due to the necessity of detaching the uterus from its ligaments before it could be operated on. In order to test this point three birds were operated on in the usual way, the uterus being prepared for operation but left intact. All 3 birds laid within 3 weeks after this operation and continued to lay eggs of normal size (table 1), colour and shape. Figure 7 shows eggs laid before and after operation.

7. *Effect of pressure on the uterus.* It appeared probable that certain malformations of eggs might be due to pressure on the uterus. To test this, it was decided to use the first bird available. While operating on No. 802 for the purpose of making a fistula a severe hemorrhage developed, so that it was not deemed advisable to complete the operation. Two pieces of cotton were, therefore, placed at each side of the uterus and the wound in the body wall closed in the usual way. The bird molted so that no eggs were laid for six weeks and then the first two were broken. The third was slightly flattened through one diameter. There was, midway between the ends, a thin, depressed and somewhat rough spot about 1 cm. in diameter.

Some of the eggs subsequently laid had a slight depression about 1 cm. wide, reaching part way around the middle of the egg. The shells on these eggs were normal. This hen was later killed, when the cotton was found gathered into one large encapsulated mass just anterior to, but not quite in contact with, the empty uterus. When expanded by an egg the uterus probably pressed against the encapsulated cotton with the results noted.

### *d. Discussion*

The results of the various operations performed agree in that there appeared to be, in each case, an effect on the shape of at least some of the eggs subsequently laid. Altering the shape and possibly size of either the isthmus or the uterus had this effect thus indicating that both these parts influence the shape of the egg. Since the eggs laid by the same hen varied from day to day it appears probable that the muscular activity of these parts of the oviduct also influences the shape of the egg. It would be difficult to interpret the results on the basis that the shape of these parts alone determines the form of the egg for, were that the case, the eggs laid after the operations should have been more uniformly abnormal in shape. On the other hand, if muscular activity alone determines shape it is difficult to account for the consistent production after an operation of the same abnormality in shape alternating with nearly normal shaped eggs when those laid before the operation were normal. The simplest explanation appears to be that the eggs laid after the operations (I2360, I2742) tended to be abnormal in shape, but that this was offset in some cases by muscular activity.

The results of the experiments on the uterus indicate that there is in some cases comparatively little rotation of the egg in this part of the oviduct. Were this the case a particular variation in shape such as a narrowing through one diameter or a depression in one place would be hard to account for since different parts should be similarly affected and presumably no region of the egg would remain in apposition to the abnormal part of the uterus long enough to be affected in the manner observed. If there is rota-

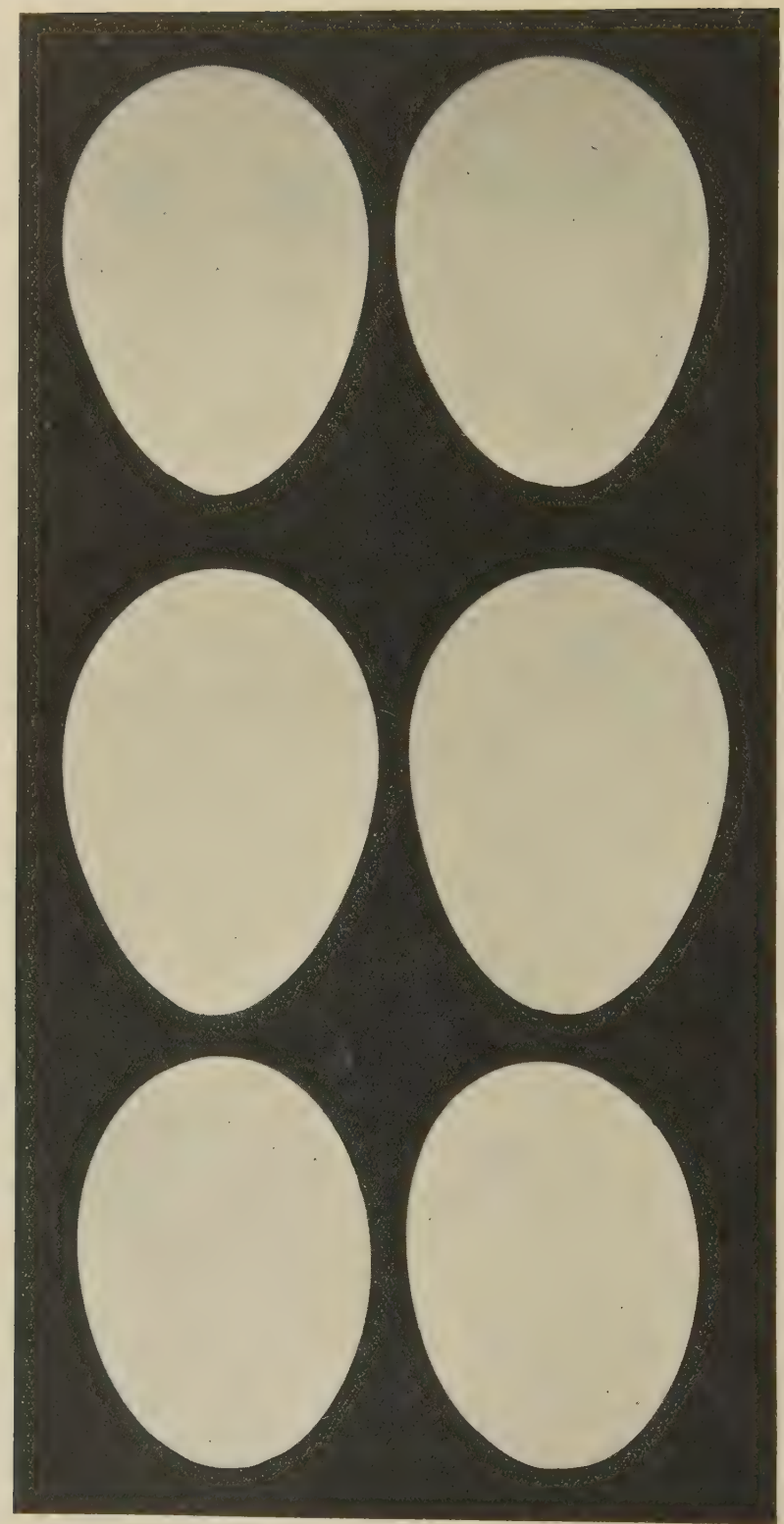

Figure 7. Eggs laid by I934 (top), I1698 (middle) and I2198 (bottom). The egg on the left was in each case laid before the operation, that on the right after the operation.

tion in such cases it must be so slow that sufficient shell material can be secreted to change the shell from a soft, modifiable structure to one that can only be changed by breaking it.

Hens such as No. I2360, that generally lay abnormal shaped eggs, sometimes lay eggs that are normal in shape. Others such as No. 802 lay eggs with abnormal depressions in the shell, which are confined to one spot on some eggs while in other cases almost the entire circumference of the egg is affected. These variations in shape are probably due to differences in the rotation of the egg in the uterus, which is presumably influenced by the muscular activity of the walls of that part of the oviduct.

The general shape of the egg, more particularly the proportion between length and breadth, is probably determined (1) by the amount of albumen secreted in the albumen part and (2) by the caliber of the oviduct, especially the isthmus. The isthmus is known to be narrower than the albumen part (Pearl and Curtis, 1912, and others). If now a narrow albumen part secretes considerable albumen around a yolk and this is then passed through a still narrower isthmus, it is apparent that the albumen would be forced to either end and the resulting elongated form would be preserved by the shell membrane deposited in the isthmus. The size of yolk is probably also a factor, since a large yolk passing through a narrow oviduct would not allow much albumen to remain around its equatorial region.

Some such explanation as this appears to be needed to account for characteristic differences in the proportion between length and breadth, and visible differences in the distribution of the albumen. Thus in the case of long, narrow eggs such as those laid by 824 (figure 4) there is very little albumen in the equatorial part of the egg around the yolk while in the case of comparatively short eggs more of the albumen is in this region of the egg.

Whether the egg is more pointed at one end than the other probably depends on the muscular activity of the walls of the albumen part and isthmus, as suggested by Ryder (1893). This would influence the proportion between length and breath (index) to some extent, since the distribution around the yolk would be affected. As already indicated, however, all variations in shape of eggs cannot be satisfactory explained solely by differences in muscular activity.

While the evidence with regard to the determination of the general shape of the egg cannot be considered satisfactory, it may tentatively be assumed that the general form of the egg is determined in the albumen part and isthmus, thus agreeing with the statement of Curtis (1914b) that the egg is generally if not always shaped when it enters the uterus. This general form may be altered in various ways in both the isthmus and the uterus. Slight and greater abnormalities in shape are apparently produced either in the isthmus or uterus or both and at present it is not possible to differentiate between them with certainty. Slight unevenness and wrinkling of the shell (I2742, 824) may be determined in the isthmus rather than in the uterus but it cannot be stated that this is always so. For the present it can only be concluded that the particular form of the egg is determined in the isthmus and the uterus and not solely in the latter, as has been thought to be the case.

### *e. Summary*

The birds used in this investigation laid eggs that varied approximately normally in shape. All eggs varied slightly in diameter. In 94 percent of the eggs laid before the birds were used for experiment the minimum diameter differed from the maximum diameter by .35 millimeters or less.

It is concluded on the basis of the following facts that (a) the isthmus influences the shape of the egg:

1. The eggs laid by a hen, after the anterior half of her isthmus had been removed, were for the most part more irregular in shape than eggs laid before the operation (figure 3).

2. Eggs laid by another hen whose isthmus was torn longitudinally and the tear closed with catgut sutures subsequently laid eggs with characteristically wrinkled shells (figure 4).

3. Eggs with very little shell have the characteristic shape of normal eggs laid by the same hens. This was true of an egg removed from the uterus of a hen with a fistula.

4. Interference with the isthmus (temporary ligation) resulted in the laying of abnormal shaped eggs for a time, with a gradual return to the laying of approximately normal eggs (figure 5).

(b) Operations on the uterus confirm earlier work which indicated that the uterus influences the shape of the egg. The following results were obtained:

1. After removing a piece 2.5 by 1.1 cm. from the ventral side of the uterus of a pullet, she at first laid a few eggs that were approximately normal in shape but later laid eggs that were flattened on one side (figure 6).

2. Hens that were similarly treated except for the final operation on the uterus laid normal shaped eggs (figure 7).

3. An egg laid after cotton was placed at the sides of the uterus had a thin-shelled depression on one side. Eggs laid later had a depression reaching more or less around the egg.

(c) It is considered probable that the general shape of the egg is determined chiefly by (1) the amount of albumen secreted in the albumen part, (2) the caliber of the lumen of the albumen part and isthmus, and (3) the muscular activity of the walls of these parts. The general shape so determined may be more or less altered in the uterus which, with the isthmus, gives each egg its particular form.

## III. Determination of the Size of the Egg

### *a. Review of the literature*

Variability in the size of hens' eggs is well known. Not only do eggs from different hens vary in length and breadth, as shown by Pearl and Surface (1914), but those of the same bird, while generally less variable, may equal the variability for the flock (Curtis 1914b). Pearl and Surface (1914) found that the absolute and relative variation in length and breadth was small, but that the egg varied more in length than in breadth. These findings agree with those of Curtis.

The authors quoted found that weight of egg was more variable than length or breadth. According to Pearl and Surface, eggs are about equally variable in bulk and weight. Either bulk or weight may, therefore, be used as a measure or criterion of size, especially so since they are very closely correlated ($r = + .9804 \pm .0012$). Weight of egg is generally the most easily obtained criterion of size, hence is generally used. Differences in the weight of eggs laid by different hens, as well as in the weight of the eggs laid by the same hen, are well known and have been studied by Pearl and Surface (1914), Curtis (1914b), Atwood and Weakley (1917), Benjamin (1920), Hadley and Caldwell (1920), Jull (1924) and others. In general it has been found that the eggs of any one hen are less variable in weight than those from a flock and that there are individual differences in the variability of the eggs laid.

In connection with the present study, the weight of the parts and variation in the weight of these is of particular importance. Curtis (1914b) found that the shell was most variable in weight as measured by the coefficient of variation, then yolk, while the albumen was least variable. The relative variability is therefore in inverse order to the mean weight of these parts. This agrees with the results obtained by Jull (1924, I), who found that the coefficients of variation for weight of egg and weight of albumen were about equal, while the coefficient of variation for weight of yolk was higher and still higher for weight of shell.

The correlation between the weight of egg and weight of the parts is, in general, in the following order: albumen, yolk, shell (Curtis 1914b, Jull 1924, I). There is considerable individual difference in the correlation between weight of egg and the weight of the parts but these individual differences were least for weight of albumen and greatest for weight of shell (Curtis). When the partial correlation was calculated Curtis found that the coefficients were in the same order but that it was doubtful whether egg weight was more closely correlated with weight of albumen than with weight of yolk. Curtis notes that the order of the coefficients of correlation is the same as the weight of the parts.

The causes of variation in the size of the egg and its parts are little known but certain relationships that throw some light on this question have been found and may be briefly referred to. Thus Curtis (1914b) found that the size of the first eggs laid depended to some extent on the age of the birds at the time laying commenced. The weight of the egg and its parts tended to increase with age, this relation being most regular in the case of the yolk. Birds that did not lay until nine months old laid eggs with yolks of similar size to those that had been laying for about three months. Conversely, a pullet that started laying when three months old laid exceptionally small eggs with unusually small yolks. More recently Lippincott (1921) has shown that the weight of the first 10 eggs is closely correlated with the age of the bird when laying commenced, and this result has been confirmed by Atwood (1923) and Jull (1924, II). Lippincott, Parker and Schaumburg (1925) found that the correlation between age and weight of eggs laid during successive 30-day periods of the first laying year is at first high but gradually decreases to insignificance and then increases again towards the end of the year.

Curtis (1914b) noted a seasonal variation in the size of the eggs laid, which she considered, to some extent, related to production and food consumption. Jull (1924, 1925) has shown that these variations are related to the time laying commenced and are also associated with increase in body weight. He has further shown that the increase in egg weight is not a measure of first year egg production as claimed by Hadley (1919).

It has been found that the position of the egg in the litter and the clutch is related to the relative size of the egg (Féré, 1897a; Curtis, 1914b; Atwood and Weakley, 1917; Jull, 1924; Atwood, 1926). Thus eggs laid on successive days generally decrease in weight but the rate of decrease is less when the birds are laying heavily (Atwood 1926). There are also exceptions where the eggs laid on successive days increase in weight and then decrease.

As a rule, no significant correlation has been found between egg weight and annual first year egg production. Jull, (1930), however, reports a significant negative correlation ($r = -0.3892 \pm 0.1249$). At the same time Marble (1930) reported that the relation between egg weight and annual egg production is non-linear, which possibly explains some earlier failures to find any relationship.

Pearl (1910) and Curtis (1914b) found that the amount of albumen secreted was related to the amount of yolk and that this relationship was represented by a parabola. Their results indicate that large yolks constitute a relatively larger part of the egg than small yolks. Atwood and Weakley, however, found that the yolk weight of eggs laid on successive days decreases proportionately less than the weight of the albumen. Jull (1924) found that albumen weight sometimes decreased while yolk weight increased and considers that the amount of albumen secreted depends on other factors besides the size of the yolk. This agrees with the greater seasonal fluctuation in weight of albumen and shell than yolk found by Curtis.

Weight of egg is positively correlated with body weight (Asmundson, 1921: Atwood 1923, 1925; Jull, 1924; Parkhurst, 1926; Upp and Thompson, 1927). None of the coefficients of correlation are high, which agrees with the results of common observation. It is of interest to note that Curtis (1914b) found some evidence that the size of the oviduct was related to the weight of bird and to size of egg but there was one wide exception to the latter relation among the four birds for which data were available.

The experiments of Benjamin (1920) and Hurst (1921) have shown that size of egg is inherited, and that small size is apparently dominant over large size. Hays (1929) finds that large eggs are made possible by a dominant autosomal gene *B*, while small eggs are due to an autosomal gene A, epistatic to gene *B*. The smallest eggs are laid by recessives of the constitution *a b*. Small egg size may then be either a dominant or recessive character.

Finally nutrition (amount and kind of food) is one of the factors influencing size of egg. Thus Kistler, Charles and Knandel (1926) found that milk in the ration apparently increased the size of the eggs laid. More direct evidence is available with regard to the effect of nutritional factors on weight of shell. The work done by Wheeler (1919), Buckner, Martin and

Peters (1928), Hart, Steenbock, Halpin, et al. (1925), Hughes, Payne and Latshaw (1924, 1925) and Taylor and Martin (1928), shows that the weight of the shell depends on the kind and amount of shell forming material and on a supply of vitamin D. Taylor and Martin found that the percentage of shell was not related to the shape or weight of the egg. They also note that there appear to be inherent differences in the percentage of shell.

### *b. Variation in size and weight*

The constants for size, shape and weight of 707 eggs laid by 67 hens before they were used for experiment are set forth in table 4 and all except the constants for weight have been discussed. The eggs in the sample here considered were slightly smaller and more variable than those used by Pearl and Surface (1914) but resembled those used by Curtis (1914b) both in weight of the egg and its parts. The mean weights of eggs and the parts were: egg 53.64 gm., yolk 16.10 gm., albumen 31.52 gm., shell 5.63 gm.

TABLE 4.—*Constants for size, shape and weight of 707 eggs laid by birds that were later operated upon. Measurements are given in millimeters, weights in grams.*

| Character | Mean | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| Length | 56.93 ± .08 | 3.02 ± .05 | 5.30 ± .10 |
| Breadth | 41.00 ± .04 | 1.51 ± .03 | 3.68 ± .07 |
| Difference in Breadth* | 0.17 ± .004 | 0.14 ± .003 | 82.35 ± 2.27 |
| Index | 71.83 ± .10 | 4.05 ± .07 | 5.64 ± .10 |
| Weight of egg | 53.64 ± .14 | 5.42 ± .10 | 10.10 ± .18 |
| " " yolk | 16.10 ± .05 | 2.11 ± .04 | 13.11 ± .24 |
| " " albumen | 31.52 ± .10 | 3.98 ± .07 | 12.63 ± .23 |
| " " shell | 5.63 ± .02 | 0.83 ± .01 | 14. 4 ± .27 |

*Difference in maximum and minimum diameter.

TABLE 5.—*Frequency distribution of differences in greatest and least diameter of 707 eggs laid prior to the use of the birds for experimental purposes.*

| Class range (mm.) | No. of eggs in each class |
|---|---|
| 0 – .11 | 272 |
| .12 – .23 | 301 |
| .24 – .35 | 90 |
| .36 – .47 | 23 |
| .48 – .59 | 9 |
| .60 – .71 | 5 |
| .72 – .83 | 4 |
| .84 – .95 | |
| .96 – 1.07 | 2 |
| 1.08 – 1.19 | |
| 1.20 – 1.31 | |
| 1.32 – 1.43 | |
| 1.44 – 1.55 | |
| 1.56 – 1.67 | 1 |
| Total | 707 |

With regard to the weight of the egg and its parts, these resemble the eggs studied by Curtis (1914b) but are slightly heavier in total weight, due to the mean weight of yolk and shell being slightly greater. These eggs were also heavier than the eggs used by Jull (1924). With regard to variability, these eggs were more variable, both as measured by the standard deviation and the coefficient of variation, than those reported by Curtis and by Jull. Some of the differences are statistically significant. The point of importance, however, is that the order of variability is the same in all cases. Thus the magnitude of the standard deviation is in the same order as the weight, while the coefficient of variation is in inverse order. The weight of shell is relatively most variable, while egg weight is least variable. In agreement with what has previously been found by others, length and breadth are much less variable than the weight of egg.

*c. Correlation of the parts of the egg.*

It would be expected that the relationships of the parts of the eggs here dealt with would differ somewhat from those found by Curtis (1914b) since they were obtained from a more heterogeneous group and it was not always possible to obtain as many from each bird as would be desirable. This is in fact the case as shown by the constants in table 6.

It will be seen (table 6) that weight of eggs is more closely correlated to breadth than to length, thus agreeing with previous findings. This is also true for weight of albumen and shell but while the coefficient of correlation for weight of yolk with breadth is slightly higher than for weight of yolk with length the difference is not significant. The weight of egg is not correlated with either of the measures of shape (index and difference in breadth) here used and this is also true of the weight of the parts of the egg, which, so far as weight of egg and index is concerned, agrees with the findings of Pearl and Surface (1914).

The coefficients of correlation between the weight of egg and the weight of the parts differ from what would be expected since the correlation between weight of yolk and weight of egg is less than between weight of shell and weight of egg. Since there is a certain amount of spurious correlation between the weight of the parts of the egg and its total weight, due to their inclusion in the total, the coefficients of correlation would be expected to be in the same order as the weight of the parts. This, indeed, was what Curtis (1914b) found to be the case. The figures here presented further differ from her findings in that there is little correlation between weight of yolk and weight of albumen and no significant correlation between yolk weight and weight of shell, while the latter is closely correlated with albumen weight. This order of relationships is also shown by the coefficients calculated between any two of these characters with the third held constant. Here y = yolk, a = albumen and s = shell. The constants obtained were as follows:

$$r_{ya.s} = + .179 \pm .025$$
$$r_{ys.a} = - .038 \pm .025$$
$$r_{as.y} = + .607 \pm .016$$

These relationships support the conclusion of Jull (1924) that the amount of albumen secreted is to a considerable extent independent of the weight of

TABLE 6.—*Coefficients of correlation for measures of size and shape of egg and for the weight of the egg and its parts based on data for 707 eggs laid by birds subsequently operated upon.*

| | Length | Breadth | Diff. in Breadth | Index | Weight of Egg | Weight of Yolk | Weight of Albumen |
|---|---|---|---|---|---|---|---|
| Breadth | +.208 ± .024 | | | | | | |
| Diff. in Breadth | −.092 ± .025 | +.116 ± .025 | | | | | |
| Index | −.758 ± .011 | +.431 ± .020 | +.166 ± .025 | | | | |
| Weight of egg | +.628 ± .015 | +.810 ± .009 | −.004 ± .025 | −.085 ± .025 | | | |
| Weight of yolk | +.428 ± .021 | +.476 ± .020 | −.131 ± .025 | −.103 ± .025 | +.538 ± .018 | | |
| Weight of albumen | +.582 ± .018 | +.726 ± .012 | +.105 ± .025 | −.079 ± .025 | +.899 ± .005 | +.197 ± .024 | |
| Weight of shell | +.279 ± .023 | +.570 ± .017 | +.008 ± .025 | +.118 ± .025 | +.636 ± .015 | +.091 ± .025 | +.611 ± .016 |

the yolk. This conclusion was indicated by the irregular increase in weight of albumen and shell as contrasted with the regular increase in the weight of the yolk with age noted by Curtis (1914b) and further supported by the observations of Atwood and Weakley (1917) and of Jull (1924).

Figures are available for thickness of shell on 400 of the 707 eggs used for these correlation studies. These four hundred eggs were selected at random and the coefficients of correlation and partial correlation calculated for thickness of shell, weight of shell, and weight of egg. Letting t = thickness of shell, s = weight of shell, and e = weight of egg, the coefficients of correlation obtained are as follows:

$r_{es} = + .604 \pm .021$ $\quad r_{es.t} = + .742 \pm .015$

$r_{st} = + .778 \pm .013$ $\quad r_{st.e} = + .849 \pm .009$

$r_{et} = + .188 \pm .033$ $\quad r_{et.s} = - .563 \pm .023$

The coefficient of correlation for weight of egg and shell is positive and of about the same magnitude as the coefficient in table 6 which was based on all the eggs available. When thickness of shell is held constant, the coefficient is increased by .138 ± .026 to + .742.

As would be expected, weight of shell is closely correlated with thickness of shell. There is also a slight positive correlation between weight of egg and thickness of shell, but, when weight of shell is held constant, this is changed to a significant negative correlation. While the amount of shell secreted is influenced by the weight of egg and, hence, of yolk and albumen, the thickness of shell is apparently only slightly affected. This does not apply to extreme fluctuation in size, such as the laying of dwarf eggs or double-yolked eggs since, in such cases, there appears to be a negative correlation between size and thickness of shell.

The evidence just presented is unsatisfactory in some ways for the purpose of determining the influence of variations in size of yolk on the amount of secretion. Using data for all the eggs laid by a single individual is also subject to the criticism that the weight (size) of the bird does not remain constant and this probably also applies to the oviduct.

The following case is of interest in this connection. A pullet that had been receiving .3 grams daily of dessicated thyroid (Armour's) since March 31st laid an egg with a much smaller yolk than usual on April 20th. She laid 5 eggs from April 10th to 18th inclusive, and another, the last, on April 22nd. The average weights of the parts of the first 5 normal eggs together with weights for the eggs laid on April 20th and 22nd are as follows:

*Weights in Grams.*

| Date laid | Yolk | Albumen | Shell | Total |
|---|---|---|---|---|
| April 10-18 | 11.91 | 32.13 | 5.51 | 49.55 |
| " 20 | 6.40 | 30.24 | 5.03 | 41.67 |
| " 22 | 10.20 | 29.83 | 5.10 | 45.13 |

In spite of the much smaller yolk in the egg laid on April 20th the weight of the albumen and shell remained nearly the same. In the egg laid April 22nd the amount of albumen was slightly less although the yolk was nearly normal in weight.

This case cannot be considered conclusive in any way but it is interesting as an example of a large decrease in the weight of the yolk without anything like as great a decrease in the amount of albumen and shell secreted. It appears to indicate that the amount secreted by the oviduct is only to a very limited extent influenced by the weight or size of the yolk.

*d. Difference in the size of eggs laid by bantams and ordinary hens.*

It has already been stated that egg weight is related to various characters including weight of bird. Some data collected on a few bantam eggs are available for comparison with ordinary hens' eggs. It was not possible to secure the eggs from birds of the same age, hence the differences in percentage of yolk, albumen and shell may not be strictly representative of differences between bantam and ordinary eggs, because such differences depend partly on the age of the hen that lays the egg. Eggs with yolks of about the same weight as those in the bantam eggs were selected for the comparison so as to eliminate this factor as far as possible.

The averages for the two groups of eggs are presented in table 7. It will be seen that the bantam eggs were shorter and narrower than the ordinary hens' eggs. The difference in width was greater than in length, hence the length-breadth index is lower. The bantam eggs were slightly less variable in width.

TABLE 7.—*Comparison of bantam eggs with ordinary hens' eggs having yolks of similar weight.*

| | 60 ordinary hens' eggs | 15 bantam eggs | Diff. |
|---|---|---|---|
| Length | 53.91 mm. | 51.09 mm. | 2.82 mm. |
| Breadth | 39.13 " | 35.67 " | 3.46 " |
| Diff. in breadth | 0.22 " | 0.09 " | 0.13 " |
| Index | 72.79 | 69.84 | 2.95 |
| Weight of egg | 46.47 gm. | 36.14 gm. | 10.33 gm. |
| Weight of yolk | 12.04 " | 12.03 " | 0.01 " |
| Weight of albumen | 29.43 " | 20.05 " | 9.38 " |
| Weight of shell | 5.00 " | 4.06 " | 0.94 " |
| Yolk—percent of total wt. | 25.97 | 33.33 | −7.36 |
| Albumen " " " | 63.29 | 55.45 | 7.84 |
| Shell " " " " | 10.74 | 11.23 | −0.49 |

The point of chief interest in these figures is the comparative amount of albumen and shell. The amount is distinctly less in the case of the bantam eggs, although the average weight of the yolk is the same for both groups. Thus for the bantams the average weight of albumen is 20.05 grams, varying from 17.42 to 22.27 grams. The corresponding average for the ordinary eggs is 29.43 grams, with a minimum weight of 24.45 grams and a maximum of 34.53 grams. There is here no overlapping in the amount of albumen secreted. The figures for shell weight are somewhat different in that the weights overlap. Thus for the bantam eggs, the average weight of shell was 4.06 grams, with a range from 2.68 to 4.52 grams, while the average for the ordinary eggs was 5.00 grams, the weight ranging from 3.63 to 5.87.

These figures indicate that difference in weight of albumen is conditioned by the weight of the bird. This agrees with evidence briefly referred to above (Jull and others) which indicated that one of the reasons for the

smaller size of the first eggs laid by early as compared with late maturing pullets was the smaller size of the early maturing pullets.

Presumably the weight of the bird is correlated with the size of the various organs, including the oviduct, since various body measurements, such as length of sternum have been found to be correlated with weight of bird (Asmundson, 1921). The correlation here is not high, which may explain why body-weight and egg weight are not closely correlated. Whatever the exact relation is between weight of the bird and its organs, the evidence now available points to the size of the oviduct as one of the factors determining the amount of albumen secreted.

### *e. Summary*

1. The mean weight of 707 eggs and their parts, laid by 67 birds before they were used for experimental purposes was as follows: yolk, 16.10 grams; albumen, 31.52 grams; shell, 5.63 grams; total weight of egg, 53.64 grams.

2. The relative variability in the weight of the parts of eggs as measured by the coefficient of variation was in inverse order to weight, that is, shell weight was most variable and albumen weight least variable and the weight of egg was relatively less variable than that of any of the parts (table 4). The weight of yolk was only slightly more variable than the weight of the albumen, but the difference is not statistically significant. These results agree in general with previously published reports.

3. Weight of egg was found to be positively correlated with the weight of each of the parts (table 6). The coeffifficient of correlation was highest for albumen—egg weight ($r = + .899$); next for shell — egg weight ($r = + .636$); and lowest for yolk — egg weight ($r = + .538$), whereas others (Curtis, Jull) have reported the lowest correlation between weight of shell and egg. Thickness of shell is closely correlated with weight of shell ($r = + .778$), but is only slightly influenced by weight of egg ($r = + .18$).

4. Weight of yolk was not correlated with weight of shell ($r = + .091$) and the coefficient of correlation between weight of yolk and albumen is also low ($r = + .197$). Weight of albumen and shell are positively correlated ($r = + .611$).

5. The correlations between the parts of the egg indicate that the amount of albumen and shell depends to only a limited extent on the size of the yolk. This is further supported by an egg that had the normal amount of albumen and shell although the yolk weighed only 6.40 grams as compared with 11.91 for 5 eggs previously laid by the same hen.

6. A comparison of 15 bantam eggs with 60 eggs having yolks of the same weight, from ordinary hens, showed that the bantam eggs had less albumen and shell (table 7). The weight of albumen was less in every case for the bantam eggs, varying from 17.42 to 22.27 grams as compared with a range of 24.45 to 34.93 grams for the ordinary eggs. This is interpreted to indicate that the amount of albumen secreted by the oviduct is to some extent dependent on the size of the bird and presumably also on the size of the oviduct.

(Part IV. will appear in the July issue).

# MODERN METHODS OF FIELD EXPERIMENTATION

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[Received for publication January 27, 1931]

During the summer of 1930 the author had an opportunity of making a study of up-to-date methods of conducting field experiments as they have been developed at the Rothamsted Experimental Station by Dr. R. A. Fisher and his staff. Since the principles on which these experiments are based are vital and should be fully understood by experimenters in this country, the following brief outline has been prepared. Particular attention has been given to methods of calculation and these are illustrated as far as possible by actual examples.

The superiority of the field plot methods developed at Rothamsted is due chiefly to the fact that they take into account the intimate relation which must exist between the arrangement of experiments and the statistical reduction of the data. Too frequently experiments are laid down without sufficient thought as to the manner in which the data are to be analyzed; when the results from such experiments are obtained we may or may *not* be able to apply tests of significance. A test of significance involves the calculation of the random error in the experiment and if the experiment has not been properly planned we cannot obtain an estimate of the random error which is valid for the comparisons we wish to make. A joint consideration, however, of plans of experiments and their statistical analysis leads to the formation of certain general principles of field plot technique. The details of the experiments and their objectives should be as individual as it is possible to make them but at the same time the general principles of field plot technique should be adhered to strictly. I shall refer to those general principles under the headings:

(1) Replication.

(2) Randomization.

(3) Local Control.

(4) Application of the Analysis of Variance.

If these principles are adhered to in agronomic experiments we can obtain a remarkable degree of standardization of methods, and no doubt can be cast upon any conclusions that may be drawn.

## Replication

The principle of replication in field plot tests is well known and understood, but as pointed out by Dr. R. A. Fisher, "It must be clearly grasped that replication serves two distinct purposes, (1) to diminish the errors to which the field results are subject . . . . , and (2) to supply an estimate of error, and this is a purpose which can be attained by no other means." In certain field experiments which have been conducted, attention has been given only to the use of replication as a means of diminishing the errors due to soil heterogeneity and errors due to measurement. Replica-

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tion is not unique in this respect as similar, although not as substantial, reductions in the errors can be obtained by varying the size and shape of the plots and by greater care in the sowing, harvesting, threshing, and taking of weights. These considerations are vital in all properly conducted experiments but they have nothing to do with the matter of obtaining an *estimate of error,* which in modern experiments is essentially an estimate of the *uncontrolled* error or that error which *must* be considered in making a comparison between any pair or pairs of treatments or varieties in the test. The latter is a random error and the former is a *systematic* one and the distinction between these should be clearly understood. Now any attempt to arrange the varieties or treatments in the replicates or blocks, in such a way as to make the systematic error a minimum will tend to increase the estimate of error and vice versa. This leads to the second general principle of field plot experiments known as *randomization* which simply stated means that supbject to certain restrictions the plots of any one variety or treatment should be arranged wholly at random. Its purpose is to balance the systematic and random errors in such a way as to make possible valid tests of significance.

### Randomization

A quotation from R. A. Fisher will serve to give a clear expression of the necessity for randomization. "The estimate of error afforded by the replicated trial depends upon differences between plots treated alike. An estimate of error so derived will only be valid for its purpose if we make sure that in the plot arrangement, pairs of plots treated alike are not nearer together or further apart than, or in any other relevant way, distinguished from pairs of plots treated differently."

This point is obvious if we begin with the simple dichotomy of a replicated experiment—we have groups of plots treated alike and groups of plots treated differently. The total variance is made up of the differences between the plots in both directions, and if we reduce the differences between plots treated differently by any sort of systematic arrangement we must automatically increase the differences between plots treated alike, and vice versa. The total variance which may be represented by V is the same regardless of the arrangement of the plots. Then if A represents the variance among the plots treated alike and B represents the variance among plots treated differently,

$$V = A + B$$

and we cannot alter either A or B without making a similar alteration in the opposite direction in the other variance. Now any comparisons we wish to make are between plots treated differently but our estimate of error is determined from the differences between plots treated alike—that is, we use the variance A to determine our estimate of error. Systematic arrangements which attempt to distribute the plots of any one variety or treatment as widely as possible over the experimental area tend to reduce B and increase A. Thus real differences between varieties or treatments are reduced and the experimental error is increased. If on the other hand, a systematic arrangement is chosen which increases the real differences, the experimental error is reduced and a still worse state of affairs is brought about. The

obvious course to take under these circumstances is to arrange the plots at random, that is, to so arrange them that any one plot is just as likely to be close to plots treated similarly as to plots treated differently.

## Local Control

In the random arrangement of varieties or treatments in a replicated experiment, certain restrictions may be placed upon these arrangements which allow of the elimination of portions of the total variance which are irrelevant in the making of comparisons. This principle is referred to as Local Control, and on experimental areas which vary in a regular way from one place to another, is very important in bringing about a reduction in the experimental error. In fact, most experimental areas are such that the exercise of Local Control is a necessary procedure in technique.

In a hypothetical experiment two varieties A and B are being compared and we may suppose that they are arranged in pairs of plots on blocks of land which vary a great deal in fertility. The arrangement may be as follows and there is high fertility at one end of the experimental field and low fertility at the other end.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A | A | B | A | A | B | B | A | B |
| B | B | A | B | B | A | A | B | A |

The *difference* between the average yield of A and the average yield of B is not affected however by the fertility gradient in the field. This difference is affected only by the soil variations between each pair of plots. Therefore, in forming an estimate of the experimental error that portion contributed by the fertility gradient from one end of the field to the other must be eliminated. This portion of the total variance is irrelevant and by eliminating it we increase the precision of our experiment.

## Analysis of Variance

The analysis of variance like any other system of statistical analysis can only be applied to properly randomized field experiments. It is characterized by features which for convenience rather than actual distinction may be enumerated as follows: (1) It provides for the division of total variability in the experiment into components each of which is capable of furnishing an independent estimate of the experimental error. The total variability is expressed as the sum of the squares of the deviations of each plot yield from the general mean. This sum of squares is divided into component sums of squares, such as those due to blocks, varieties, and error. (2) The mechanism is furnished for the exercise of Local Control by the elimination of those sums of squares from the sum of squares giving an estimate of the experimental error, which are irrelevant to the making of comparisons between pairs of varieties. This results in a reduction of the experimental error. (3) It makes possible the comparison of estimates of variances due to the components of the experiment, such as the variety estimate with the soil heterogeneity estimate. These tests furnish a rigorous criterion of the

amount of information furnished by the experiment and unless significant differences are found it may be advisable to abandon all further analysis and in all probability it will not be worth while to repeat the experiment. This, as will be shown later by examples, is one of the most important features of the Analysis of Variance as it enables us to permanently discard types of experiments which are not yielding valuable information. It also enables us in analyzing the data from any one experiment to deal only with those phases of it which have given significant results. (4) In addition to the above points the Analysis of Variance takes due account of the number of *degrees of freedom* contributed by each component giving an estimate of the variance. In this respect therefore it takes due account of the distribution of statistics calculated from small samples. In field experiments the number of degrees of freedom is usually small and unless the correct distributions are used in tests of significance, serious errors may be made.

## Types of Randomized Experiments

1. *Randomized Blocks.*

This type of experiment is best illustrated by the following plan showing the arrangement of the plots of 8 varieties in the experimental field. The varieties are designated A, B, C, D, E, F, G, H. For the sake of simplicity four blocks are illustrated although such an experiment would probably be conducted with six blocks. It will be noted that the arrangement is purely random, with the one restriction that any one variety can occur only once in one block.

| | | |
|---|---|---|
| I | G A H D<br>F B C E | E D H A<br>G C F B |
| III | B H D F<br>C E A G | G F C A<br>E D B H |

II IV

The method of randomizing the varieties is one which can easily be worked out by the experimenter. In this case numbers from 1 to 8 were assigned at random to the 8 varieties by opening a book of random numbers and dividing two figure numbers by 8. The remainder was then taken as a random single figure number. Thus 46/8, = 5 and 6 over. The number 6 is then taken to represent A. When 8 goes evenly into the two figure number we take 8 as the random single figure number. It is obvious also in this case that all two figure numbers above 96 should be discarded. In the above case the numbers assigned were:

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| 8 | 3 | 7 | 5 | 6 | 2 | 1 | 4 |

Then repeating the process for each block we assign the varieties to the plots within the block. For block I the random single figure numbers obtained were 1, 8, 4, 5, 2, 3, 7, 6, and the varieties were accordingly placed in the block in the order shown. Whatever the process used for randomization it should be carefully thought out in order that all numbers may have an equal chance of occurring.

2. *The Latin Square.*

This is a plan of special importance for making accurate tests on a small number of varieties or treatments. It involves the use of as many replicates as there are treatments or varieties so that ordinarily we would

not go beyond the 6 x 6, and very rarely beyond the 8 x 8 Latin Square. The principle is illustrated by means of the following diagram of a 5 x 5 square:

| | | | | |
|---|---|---|---|---|
| E | B | C | D | A |
| A | C | D | E | B |
| D | E | B | A | C |
| C | D | A | B | E |
| B | A | E | C | D |

The square is divided into five columns and five rows, and in each column and row any one treatment can occur only once. Otherwise the arrangement is a purely random one.

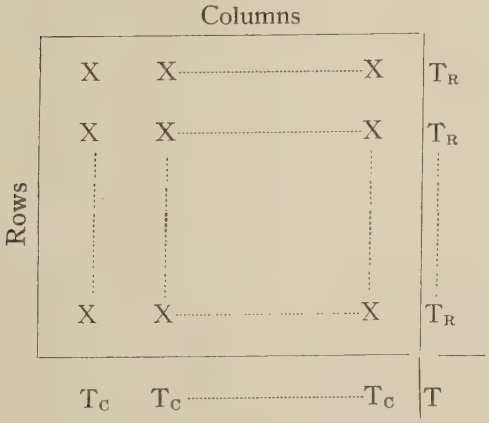
3. *Other Possible Types.*

While the Randomized Block and Latin Square types of experiments are standard and meet the requirements of nearly all workers, other types may be devised which will be more applicable to particular tests. Before different types are used however, it is well to know whether or not the Analysis of Variance tests will be applicable to them.

## Calculations and Formulae for Analysis of Variance Tests

In a recent pamphlet by Doctors R. A. Fisher and J. Wishart, "The Arrangement of Field Experiments and the Statistical Reduction of the Results", Imperial Bureau of Soil Science, Technical Communication, No. 10, complete details are given as to the arithmetical procedure and analysis of Latin Square and Randomized Block experiments. These are as simple and direct as it is possible to make them; the methods used below are adapted from this pamphlet.

A Latin Square experiment after the yields have been obtained may be represented as follows:




Here X represents the yield of a single plot, and $T_R$ the total for a single row, $T_C$ the total for a single column, and T the grand total of all of the plots. There are n rows, columns, and varieties, so that we shall have n $T_R$'s, n $T_C$'s and n $T_V$'s. In the latter $T_V$ stands for the total of a single variety.

We then have to calculate the sums of squares:

1. Total sum of squares, $\overset{n^2}{\underset{1}{S}}(x-\bar{x})^2$

$$= S(x)^2 - \frac{T^2}{n^2} \quad (n^2-1) \text{ Degrees of freedom.}$$

that is, we square all of the x values, summate, and subtract the square of the grand total divided by the total number of plots.

2. Sum of squares for rows, $n \sum_{1}^{n} (\bar{x}_R - \bar{x})^2$

$$= \frac{S(T_R)^2}{n} - \frac{T^2}{n^2} \quad (n-1) \text{ Degrees of freedom.}$$

We square all the row totals, summate, and divide by the number of plots in one row. Then $\frac{T^2}{n^2}$ which has already been calculated is subtracted.

3. Sum of squares for columns, $n \sum_{1}^{n} (\bar{x}_C - \bar{x})^2$

$$= \frac{S(T_C)^2}{n} - \frac{T^2}{n^2} \quad (n-1) \text{ Degrees of freedom.}$$

We subtract $\frac{T^2}{n^2}$ from the sum of the squares of the column totals divided by n.

4. Sum of squares for treatments, $n \sum_{1}^{n} (\bar{x}_V - \bar{x})^2$

$$= \frac{S(T_V)^2}{n} - \frac{T^2}{n^2} \quad (n-1) \text{ Degrees of freedom.}$$

We subtract $\frac{T^2}{n^2}$ from the sum of the squares of the variety totals divided by n.

5. Sum of squares for error, or the residual sum of squares not accounted for by rows, columns, or varieties.

The complete expression for the sums of squares is:

$$\underset{1}{\overset{n^2}{S}}(x-\bar{x})^2 = \underset{1}{\overset{n}{nS}}(\bar{x}_R-\bar{x})^2 + \underset{1}{\overset{n}{nS}}(\bar{x}_C-\bar{x})^2 + \underset{1}{\overset{n}{nS}}(\bar{x}_V-\bar{x})^2 + S(d^2)$$

(1) (2) (3) (4) (5)

in which the term on the extreme right is the sum of squares for error. The other four terms have been calculated as above so the latter term may be obtained by subtracting (2) + (3) + (4) from (1).

In connection with these calculations it is useful to know that the plot yields in the square may first be replaced by deviations from a working mean. This reduces the labour to a marked extent and the sums of squares we obtain are exactly the same as those obtained by the above method.

The next step in calculation is to divide the sums of squares by the appropriate number of degrees of freedom in order to obtain an estimate of the variance from each component of the experiment. The degrees of freedom are obtained as above for rows, columns, varieties, and total; and it remains only to find the degrees of freedom for error. This is again

obtained by differences similar to the manner in which the sum of squares for error is obtained. The complete expression for degrees of freedom is:

$$\underset{(1)}{n^2-1} = \underset{(2)}{(n-1)} + \underset{(3)}{(n-1)} + \underset{(4)}{(n-1)} + \underset{(5)}{(n^2-3n+2)}$$

Term (5) is obtained by subtracting $3(n-1)$ from $(n^2-1)$.

The remainder of the work can be illustrated in the form of a table which is the best form in which to carry through the calculations after the sums of squares have been obtained.

TABLE 1. *Analysis of Variance—Latin Square*

| Sums of Squares | Degrees Freedom | Estimate of Variance | ½ $\log_e$ Previous column | |
|---|---|---|---|---|
| (2) Rows $\frac{n}{1} S(\bar{x}_R-\bar{x})^2$ | $n-1$ | $\frac{n}{1} S(\bar{x}_R-\bar{x})^2/n-1$ | | |
| (3) Columns $\frac{n}{1} S(\bar{x}_C-\bar{x})^2$ | $n-1$ | $\frac{n}{1} S(\bar{x}_C-\bar{x})^2/n-1$ | | |
| (4) Varieties $\frac{n}{1} S(\bar{x}_V-\bar{x})^2$ | $n-1$ | $\frac{n}{1} S(\bar{x}_V-\bar{x})^2/n-1$ | (4)— | } Difference=$z$ |
| (5) Error $S(d^2)$ | $n^2-3n+2$ | $S(d)^2/(n^2-3n+2)$ | (5)— | |
| (1) Total $\frac{n^2}{1} S(x-\bar{x})^2$ | $n^2-1$ | | | |

The last column gives half the *natural* logarithm of the estimate of variance in the same line, and is most easily obtained by writing down the *common* logarithms and multiplying each of these on the machine by 1.15129, which is ½ $\log_e 10$.

This brings us to the application of tests of significance to the experiment as a whole. In such an experiment as this we shall want to know if the estimate of variance due to varieties is significantly greater than that due to error. If there are no varietal differences we would expect the variance estimated from the varieties to differ from that due to error only by an amount which could easily be obtained by chance. We therefore, as shown in the table, take the difference between ½ $\log_e$ for (4) and ½ $\log_e$ for (5), obtaining the statistic known as $z$. We next enter R. A. Fisher's table of $z$ and find the value of $z$ at the 5% point for $n_1 = n-1$ and $n_2 = n^2-3n+2$. If our calculated $z$ value exceeds this we conclude that varietal differences in the experiment are significant. Otherwise we would proceed no further with the analysis of the data, except in so far as we might suspect that on further analysis of the treatment sum of squares some effect might account for practically the whole of the observed variation, and for this smaller number of degrees of freedom might give a significant $z$. Such a test, however, must be used with caution.

The calculations involved in a Randomized Block experiment are very similar to those for the Latin Square. We can represent such an experiment as follows:

| | | | | | |
|---|---|---|---|---|---|
| A | X X.....X | X X.....X | B | $T_B$ = Total for one block. | |
| | X X.....X | X X.....X | | $T_V$ = Total for one variety. | |
| C | X X.....X | X X.....X | D | T = Grand Total. | |
| | X X.....X | X X.....X | | | |

In this experiment there are 4 blocks but there may be any number up to 8 or 10 and we represent the number of blocks by k. The number of varieties or plots in each block will be represented by n and therefore the total number of plots by nk. The complete expression for sums of squares is:

$$\underset{1}{\overset{nk}{S}}\ (x-\bar{x})^2 = \underset{1}{\overset{k}{nS}}(\bar{x}_B-\bar{x})^2 + \underset{1}{\overset{n}{kS}}(\bar{x}_V-\bar{x})^2 + S(d^2)$$

(1) (2) (3) (4)

and the corresponding one for the degrees of freedom:

$$(nk-1) = (k-1) + (n-1) + (n-1)(k-1)$$

(1) (2) (3) (4)

The first step is to calculate the totals for each block, for each variety, and the grand total. There will be k block totals, and n variety totals.

(1) Sum of squares — total $\underset{1}{\overset{nk}{S}}(x-\bar{x})^2 = S(x)^2 - \frac{T^2}{nk}$

(2) Sum of squares — blocks $\underset{1}{\overset{k}{nS}}(\bar{x}_B-\bar{x})^2 = \frac{S(T_B)^2}{n} - \frac{T^2}{nk}$

(3) Sum of squares — varieties $\underset{1}{\overset{n}{kS}}(\bar{x}_V-\bar{x})^2 = \frac{S(T_V)^2}{k} - \frac{T^2}{nk}$

(4) Sum of squares for error is then obtained by subtracting (2) + (3) from (1).

The Analysis of Variance then takes the form shown in table 2.

TABLE 2. *Analysis of Variance—Randomized Block.*

| | Sums of Squares | Degrees of Freedom | Estimates of Variance | ½ $\log_e$ (previous line) |
|---|---|---|---|---|
| (2) Blocks | $\underset{1}{\overset{k}{nS}}(\bar{x}_B-\bar{x})^2$ | k–1 | $\underset{1}{\overset{k}{nS}}(\bar{x}_B-\bar{x})^2/k-1$ | |
| (3) Varieties | $\underset{1}{\overset{n}{kS}}(\bar{x}_V-\bar{x})^2$ | n–1 | $\underset{1}{\overset{n}{kS}}(\bar{x}_V-\bar{x})^2/n-1$ | ——— } Difference=$z$ |
| (4) Error | $S(d^2)$ | (k–1)(n–1) | $S(d^2)/(k-1)(n-1)$ | ——— } |
| (1) Total | $\underset{1}{\overset{nk}{S}}(x-\bar{x})^2$ | nk–1 | | |

The procedure in determining the significance of varietal differences is then identical with that for the Latin Square.

From the analysis of variance table the standard error of the experiment may be calculated directly. Thus in the Latin Square the standard error of a single plot is the square root of the error estimate of variance.

$$(S) \quad \text{Standard Error} = \sqrt{\frac{S(d^2)}{n^2-3n+2}} = S_1$$

Similarly for the Randomized Block experiments:

$$(S) \quad \text{Standard Error} = \sqrt{\frac{S(d^2)}{(k-1)(n-1)}} = S_2$$

These may be expressed as standard errors of means of varieties.

$$\text{Latin Square—Standard Error of Mean} = \frac{S_1}{\sqrt{n}}$$

$$\text{Randomized Block— " " " "} = \frac{S_2}{\sqrt{k}}$$

Frequently it is desirable to express these standard errors in percentages of the general mean of the experiment. If $\bar{x}_L$ is the general mean of a Latin Square experiment and $\bar{x}_R$ the mean of a Randomized Block experiment:

$$\text{Latin Square — Standard Error in Percent} = \frac{S_1 \times 100}{\sqrt{n} \times \bar{x}_L}$$

$$\text{Randomized Block — " " " "} = \frac{S_2 \times 100}{\sqrt{k} \times \bar{x}_R}$$

## Complex Experiments

For simple Latin Square and Randomized Block experiments the arithmetical procedure is sufficiently easy to be followed directly from the methods given above. In the pamphlet by Fisher and Wishart already mentioned, anyone interested may follow through the arithmetic of the examples given there.

It is in the designing and statistical analysis of more complicated experiments that a closer study of the principles is necessary, and it may perhaps be a help to some workers to follow through the detailed work of such an experiments that a closer study of the principles is necessary, and it may perhaps be Rothamsted Experimental Station, 1927-1928, and worked out by Dr. Wishart.

The purpose of the experiment planned was to determine the response of potatoes to different kinds and amounts of nitrogen fertilizers. The kinds of fertilizers are Urea, Cyanamide and Sulphate of Ammonia. The amounts of each to be applied are determined from common practice as 0, 1½, and 3 cwts. per acre of Sulphate of Ammonia, the others being equivalent in nitrogen. The 1½ cwt. rate was considered a single dressing, and the 3 cwt. a double dressing. It is obvious that we must have for our comparisons plots receiving no fertilizer, plots receiving a single dressing of each, and plots receiving a

double dressing of each. Further, each of these must be adequately replicated. There will be 7 distinct treatments which may be represented as:

0, 1 U, 1 C, 1 S, (Single dressing) 2 U, 2 C, 2 S, (Double dressing)

U = Urea
C = Cyanamide
S = Sulphate of Ammonia
1, 2, = Single and double dressings.

There must be therefore, at least 7 plots in each block, but we are going to compare single dressings of all fertilizers and double dressings of all fertilizers with no fertilizer, and if we have only 7 plots we will be comparing groups of 3 plots with 1 which will not be as fair a comparison as we would like to make. Consequently we introduce 3 control plots in each block and we then have a total of 9 plots in each block.

0(a) 0(b) 0(c) 1U, 1C, 1S, 2U, 2C, 2S,

where the 0 plots are represented for convenience only as (a), (b), and (c).

The number of blocks to be used is purely arbitrary, depending on the amount of land available, the degree of precision required, etc. In this case 4 blocks were used and when completely randomized the plan of the experiment was as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $0_{(a)}$ | 1U | 2S | $0_{(a)}$ | $0_{(b)}$ | 2C | |
| A | 2U | 1C | 1S | $0_{(c)}$ | 2U | 2S | B |
| | 2C | $0_{(b)}$ | $0_{(c)}$ | 1C | 1S | 1U | |
| | 1S | 2S | 1U | 2U | 2C | $0_{(a)}$ | |
| C | 2U | 2C | $0_{(a)}$ | 1U | 1C | 1S | D |
| | 1C | $0_{(b)}$ | $0_{(c)}$ | 2S | $0_{(b)}$ | $0_{(c)}$ | |

After the experiment was completed the yields of single plots were set up as in table 3.

TABLE 3.—*Actual yields per plot in pounds.*

| Block | $0_{(a)}$ | $0_{(b)}$ | $0_{(c)}$ | 1 U | 1 C | 1 S | 2 U | 2 C | 2 S |
|---|---|---|---|---|---|---|---|---|---|
| A | 410 | 432 | 411 | 436 | 426 | 399 | 407 | 424 | 362 |
| B | 361 | 361 | 369 | 374 | 376 | 436 | 382 | 352 | 332 |
| C | 372 | 361 | 338 | 399 | 380 | 456 | 381 | 371 | 418 |
| D | 355 | 327 | 289 | 376 | 362 | 315 | 383 | 361 | 329 |

These figures are quite large so it is convenient to tranform them into deviations from a working mean.

TABLE 4.—*Deviations of Yields per plot from working mean of 380.*

| Block | $0_{(a)}$ | $0_{(b)}$ | $0_{(c)}$ | 1 U | 1 C | 1 S | 2 U | 2 C | 2 S | Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 30 | 52 | 31 | 56 | 46 | 19 | 27 | 44 | −18 | $287 = T_a$ |
| B | −19 | −19 | −11 | − 6 | − 4 | 56 | 2 | −28 | −48 | $-77 = T_b$ |
| C | − 8 | −19 | −42 | 19 | 0 | 76 | 1 | − 9 | 38 | $56 = T_c$ |
| D | −25 | −53 | −91 | 4 | −18 | −65 | 3 | −19 | −51 | $-323 = T_d$ |
| Totals | −22 | −39 | −113 | 65 | 24 | 86 | 33 | −12 | −79 | −57 = T |
| | | −174 | | | 175 | | | −58 | | |
| | | $= T_0$ | | | $= T_1$ | | | $= T_2$ | | |

The calculation of sums of squares is then carried out as below:

1. *Total sum of squares.*

| No. | Squares |
|---|---|
| 30 | 900 |
| −19 | 361 |
| − 8 | 64 |
| ⋮ | ⋮ |
| −51 | 2601 |
| Sum | = 49393 |

$\left(S(x)^2 - \frac{T^2}{nk}\right)$ n = 9 and k = 4

$= 49393 - \frac{(-57)^2}{36} = 49393 - 90.25 = 49302.75$

Degrees of freedom (nk−1) = 35

2. *Sum of squares for blocks.* $\left(\frac{S(T_B)^2}{n} - \frac{T^2}{nk}\right)$

| No. | Squares |
|---|---|
| 287 | 82369 |
| − 77 | 5929 |
| 56 | 3136 |
| −323 | 104329 |
| Sum | = 195763 |

$\frac{195763}{9} - 90.25 = 21661.19$

Degrees of freedom (k−1) = 3

3. *Sum of squares for treatments.* $\left(\frac{S(T_V)^2}{k} - \frac{T^2}{nk}\right)$

| No. | Squares | |
|---|---|---|
| 65 | 4225 | |
| 24 | 576 | |
| 86 | 7396 | |
| 33 | 1089 | |
| −12 | 144 | Total |
| −79 | 6241 | 19671 |
| −174 | 30276 | 30276 |

$\frac{19671}{4} + \frac{30276}{12} - 90.25 = 7350.50$

Degrees of freedom $(n^1-1) = 6$ where $n^1$ is here the number of totals squared and summed.

The variation introduced here in the calculation of the sum of squares for treatments should be noticed carefully. Each of the first six numbers are totals of *four* plots while the last number is a total of *twelve* plots, so

that we have to add these separately and divide by the corresponding number of plots entering into the totals.

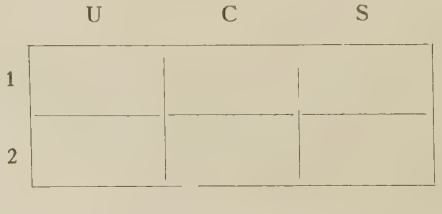
4. *Sum of squares for error will be calculated as the Analysis of Variance table is set up.*

TABLE 5.—*Simple analysis of variance.*

| Sums of Squares | | Degrees of Freedom | Variance | ½ Loge |
|---|---|---|---|---|
| Blocks | 21661.19 | 3 | 7220.40 | |
| Treatments | 7350.50 | 6 | 1225.08 | 3.5554 |
| Error | 20291.06 | 26 | 780.42 | 3.3299 |
| Total | 49302.75 | 35 | | $z = .2255$ |

Entering Fisher's table of $z$ for $n_1 = 6$ and $n_2 = 26$, we find that $z$ at the 5% point is .4529. This is greater than our calculated $z$ and we conclude that the treatment variance is not sufficiently greater than the error variance that it could not have occurred by chance. Our experiment may show something however with regard to the effects of different quantities and qualities of nitrogenous fertilizer. Therefore we go further now and examine the significance of the separate effects of quantity and quality of nitrogen and the interaction between these two. If the interaction is significant it means for example that some forms of nitrogen give an increasing effect with quantity while others do not, or perhaps decrease the yield. This is an especially important phase of field plot tests of this kind and its study produces information which can be obtained in no other way.

The procedure in further analyzing the treatment variance is to split up the sum of squares for treatments into its components. The process of splitting up the sum of squares should first be outlined on the basis of the division of degrees of freedom. We have a total of 6 degrees of freedom for treatments which must be split up into three parts, quantity of N, quality of N, and the interaction between the two. We have 3 quantities and 3 qualities, so that each must provide (3–1) = 2 degrees of freedom. In general, when an interaction is being studied, the number of degrees of freedom attributed to the interaction is the product of the degrees of freedom contributed by the interacting factors. In this case since quantity of N provides 2, and quality of N 2 degrees of freedom, the interaction should provide 4 degrees of freedom, but we have to modify this slightly in that an interaction can only be obtained from treated plots. Each of the qualities, U, C, and S, are represented by two quantities 1, and 2, so that the interaction table may be represented by:



in which there are 2 degrees of freedom. The scheme for dividing up the 6 degrees of freedom due to treatment is then as follows:

| | | | |
|---|---|---|---|
| Treatments — 6 | Quant. | N (0, 1, 2) | = 2DF |
| | Qual. | N (U, C, S) | = 2DF |
| | Inter. Quant. & Qual. | | = 2DF |

The calculation of the sums of squares is now straightforward.

1. *Quantity N.*

| No. | Squares |
|---|---|
| –174 | 30276 |
| 175 | 30625 |
| – 58 | 3364 |
| – 57 | 64265 |

$$\frac{S(T_{qt})^2}{n} - \frac{T^2}{nk} = \frac{64265}{12} - 90.25 = 5265.167$$

Note (n = 12) and (k = 3).

2. *Quality N.*

$$\frac{S(T_{q1})^2}{n} - \frac{T^2}{nk} = \frac{9797}{8} - \frac{(117)^2}{24} = 1224.625 - 570.375 = 654.250$$

| No. | Squares |
|---|---|
| 98 | 9604 |
| 12 | 144 |
| 7 | 49 |
| 117 | 9797 |

Note that numbers squared are totals for urea, cyanamide and sulphate. Total number of plots is 24 and the grand total is now 117. Also, (n = 8) and (k = 3).

3. *Interaction of Quantity and Quality of N.*

| | U | C | S | |
|---|---|---|---|---|
| 1 | 65 | 24 | 86 | 175 |
| 2 | 33 | –12 | –79 | – 58 |
| | 98 | 12 | 7 | 117 |

We form a new table giving the totals for each kind of fertilizer when applied in different amounts. To get the sum of squares for interactions we must eliminate the separate effects of quantity and quality. Consequently we calculate the total sum of squares for this table and subtract the sums of squares for quantity and quality.

(a) *Total*

| | |
|---|---|
| 65 | 4225 |
| 33 | 1089 |
| 24 | 576 |
| –12 | 144 |
| 86 | 7396 |
| –79 | 6241 |
| 117 | 19671 |

$$\frac{19671}{9} - \frac{(117)^2}{24} = 4347.375$$

(b) *Quantity (N only)*

$$(175 + 58)^2 = 54289$$

$$\frac{54289}{24} = 2262.042$$

(c) *Quality*

As above, under (2) = 654.250

(d) *Interactions*

| | |
|---|---|
| (a) | = 4347.375 |
| Subtract (b) | = 2262.042 |
| Subtract (c) | = 654.250 |
| Remainder | = 1431.083 |

Under 3(b) it should be noted that a short method of obtaining the sum of squares is used. This method can be very conveniently applied in such cases and especially in determining the sum of squares in (2 x 2) interaction tables. We can represent a (2 x 2) table as follows:

| | A | B | Total |
|---|---|---|---|
| 1 | $x_1$ | $x_2$ | $x_1 + x_2$ |
| 2 | $x_3$ | $x_4$ | $x_3 + x_4$ |
| Total | $x_1+x_3$ | $x_2+x_4$ | S(x) |

It represents the interaction of A, B, with 1, 2. Each entry in the table represents the yield of n plots and therefore the total number will be 4n.

The formulae for sums of squares can then be shortened.

1. Sum of squares for (1, 2) $= (\overline{x_1 + x_2} - \overline{x_3 + x_4})^2/4n$
2. Sum of squares for (A, B) $= (\overline{x_1 + x_3} - \overline{x_2 + x_4})^2/4n$
3. Sum of squares for interaction $= (\overline{x_1 + x_4} - \overline{x_2 + x_3})^2/4n$.

Item (3) saves a great deal of labor as the complete formula for the same step would be:

$$\frac{(S(x))^2}{n} + \frac{(S(x))^2}{4n} - \frac{(x_1+x_2)^2 + (x_2+x_3)^2}{2n} - \frac{(x_1 + x_3)^2 + (x_2+x_4)^2)}{2n}$$

We are now ready to set up the complete Analysis of Variance.

TABLE 6.—*Complete analysis of variance.*

| Sum of Squares | D.F. | Variance | ½ Loge | |
|---|---|---|---|---|
| Blocks | 21661.19 | 3 | 7220.40 | |
| Quant. N. | 5265.17 | 2 | 2632.58 | 1.6353 |
| Qual. N. | 654.25 | 2 | 327.12 | z = .608 |
| Interaction | 1431.08 | 2 | 715.54 | |
| Error | 20291.19 | 26 | 780.42 | 1.0273 |
| Total | 49302.75 | 35 | | |

For $(n_1 = 2)$ $(n_2 = 26)$ z at 5% point = .607

The variances for quality of nitrogen and for the interactions are actually less than for error so these effects are clearly insignificant. The quantity of nitrogen however, is effective, and this is the only phase of the experiment which we need to analyze further. Accordingly we set up a table giving the final results, the chief object being to determine the relative effects of single and double dressings of nitrogen.

TABLE 7.—*Summary of results.*

| | 0 | 1U | 1C | 1S | 2U | 2C | 2S | Mean | Stand. Error |
|---|---|---|---|---|---|---|---|---|---|
| Lbs. | 4386 | 1585 | 1544 | 1606 | 1553 | 1508 | 1441 | | |
| Tons | 6.53 | 7.08 | 6.89 | 7.17 | 6.93 | 6.73 | 6.43 | 6.76 | 0.249 |
| % | 96.6 | 104.7 | 102.0 | 106.1 | 102.6 | 99.6 | 95.2 | 100.0 | 3.69% |
| Tons | 6.53 | | 7.05 | | | 6.70 | | 6.76 | 0.144 |
| % | 96.6 | | 104.3 | | | 99.1 | | 100.0 | 2.13% |

The standard errors may be calculated as shown above:

$$S \text{ (mean of 4 plots)} = \sqrt{\frac{780.42}{4}}$$

$$S \text{ (mean of 12 plots)} = \sqrt{\frac{780.42}{12}}$$

where the result is expressed in pounds rather than in tons. The most convenient method however, is to determine the standard error in percent of the average totals of 4 plots and 12 plots. The average total of 4 plots is 1513.7 and for 12 plots it is 4541. Then we calculate:

$$S(\text{in } \% \text{ for 12 plots}) = \sqrt{\frac{780.42 \times 12 \times 100}{4541}} = 2.13\ \%$$

$$2.13\% \text{ of } 6.76 = 0.144$$

$$S(\text{in } \% \text{ for 4 plots}) = \sqrt{\frac{780.42 \times 4 \times 100}{1513.7}} = 3.69\ \%$$

$$3.69\% \text{ of } 6.76 = 0.249$$

The last operation serves to convert the percentage error into tons per acre .

In operating with the standard error of an experiment to determine the significance of differences between treatments, it is convenient to consider as significant only those differences which are 3 times the standard error. If S is the standard error of the experiment, the standard error of a difference is $\sqrt{2} \times S$. A difference should be $2 \times \sqrt{2} \times S$, to be significant, which is very close to $3 \times S$. This applies when there is a sufficient number of degrees of freedom. For smaller numbers of degrees of freedom the difference must be greater than $2 \times \sqrt{2} \times S$.

Table 7 shows that between the three kinds of nitrogen fertilizers either in the single dressing or in the double dressing group none of the differences approach $3 \times 3.69\% = 11.07\%$, and therefore they cannot be judged significant. This is in agreement with the analysis of variance which showed that quality of nitrogen was not a significant factor. The second

row of figures at the foot of the table summarizes the quantity effect. The difference between single dressing and no fertilizer is 7.7% which is slightly greater than three times the standard error. This effect may be judged significant but the double dressing has not produced a noticeable effect. While the effect of quantity is significant as shown by the analysis of variance this is only true for the single dressing.

This concludes the analysis of our experiment. This particular experiment does not seem to have given a great deal of information but it serves exceedingly well to illustrate the manner in which the analysis of variance can be used to exclude irrelevant information, allowing us to concentrate on the phases which are really giving significant results.

## Analysis of Variance Applied to Seasonal Effects in Field Experiments

In a properly planned experiment the analysis of variance furnishes a convenient mechanism for sorting out the effect of different seasons in experiments conducted on the same plots over a period of years. This is particularly important in fertilizer experiments where certain effects are cumulative and others perhaps rise to a maximum and then remain stationary or decrease. In experiments with perennial crops it may also be advantageous to be able to sort out the effect of the seasons. Some varieties or crops may show a decided response to seasonal effects while others may respond to a much lesser extent. Such an effect will be evident from the analysis of variance.

In order to demonstrate the method a hypothetical example has been set up which is modelled after an actual experiment which has been carried out at Rothamsted, in order to distinguish seasonal effects in a trial of high, medium, and low soluble slag phosphate.

In the hypothetical experiment there are four treatments in a 4 × 4 Latin Square and results have been obtained during four seasons designated I, II, III, and IV. The diagrams give the yields per plot during the four seasons and these may be related to the treatments by reference to the single diagram which shows the position of the treatments during the four years in which the trial was conducted.

| Rows \ Columns | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | D | A | C | B |
| 2 | A | C | B | D |
| 3 | B | D | A | C |
| 4 | C | B | D | A |

Position diagram.

*Plot Yield Diagrams*

I.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 10 | 16 | 12 | 14 |
| 2 | 12 | 7 | 8 | 6 |
| 3 | 12 | 8 | 11 | 7 |
| 4 | 8 | 9 | 6 | 10 |

II.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 6 | 10 | 7 | 8 |
| 2 | 8 | 5 | 6 | 4 |
| 3 | 9 | 4 | 9 | 7 |
| 4 | 7 | 9 | 6 | 8 |

III.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 9 | 14 | 8 | 10 |
| 2 | 10 | 9 | 9 | 8 |
| 3 | 11 | 6 | 10 | 7 |
| 4 | 7 | 8 | 7 | 9 |

IV.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 4 | 12 | 7 | 10 |
| 2 | 10 | 7 | 9 | 6 |
| 3 | 10 | 9 | 11 | 9 |
| 4 | 6 | 8 | 6 | 8 |

In order to carry out the calculations four tables of yields must be prepared. These give the rows, columns, and treatment totals by seasons, and the treatment totals for each row during the four seasons.

Rows

| Seasons | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| I. | 52 | 33 | 38 | 33 | 156 |
| II. | 31 | 23 | 29 | 30 | 113 |
| III. | 41 | 36 | 34 | 31 | 142 |
| IV. | 33 | 32 | 39 | 28 | 132 |
| | 157 | 124 | 140 | 122 | 543 |

Columns

| Seasons | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| I. | 42 | 40 | 37 | 37 |
| II. | 30 | 28 | 28 | 27 |
| III. | 37 | 37 | 34 | 34 |
| IV. | 30 | 36 | 33 | 33 |
| | 134 | 141 | 132 | 131 |

Treatments

| Seasons | A | B | C | D |
|---|---|---|---|---|
| I. | 49 | 43 | 34 | 30 |
| II. | 35 | 32 | 26 | 20 |
| III. | 43 | 38 | 31 | 30 |
| IV. | 41 | 37 | 29 | 25 |
| | 168 | 150 | 120 | 105 |

Treatments

| Rows | A | B | C | D |
|---|---|---|---|---|
| 1 | 52 | 42 | 34 | 29 |
| 2 | 40 | 32 | 28 | 24 |
| 3 | 41 | 42 | 30 | 27 |
| 4 | 35 | 34 | 28 | 25 |
| | 168 | 150 | 120 | 105 |

The method of calculating the sums of squares is as follows:

1. *Seasons.*

| No. | Square |
|---|---|
| 156 | 24336 |
| 113 | 12769 |
| 142 | 20164 |
| 132 | 17424 |
| 543 | 74693 |

$$\frac{74693}{16} - \frac{(543)^2}{64} = 4668.31 - 4607.02 = 61.29$$

2. *Rows*

| No. | Square |
|---|---|
| 157 | 24649 |
| 124 | 15376 |
| 140 | 19600 |
| 122 | 14884 |
| 543 | 74509 |

$$\frac{74509}{16} - 4607.02 = 49.79$$

3. *Columns*

| No. | Square |
|---|---|
| 139 | 19321 |
| 141 | 19881 |
| 132 | 17424 |
| 131 | 17161 |
| 543 | 73787 |

$$\frac{73787}{16} - 4607.02 = 4.67$$

4. *Treatments*

| No. | Square |
|---|---|
| 168 | 28224 |
| 150 | 22500 |
| 120 | 14400 |
| 105 | 11025 |
| 543 | 76149 |

$$\frac{76149}{16} - 4607.02 = 152.29$$

5. *Residual (a)*

| No. | Squares |
|---|---|
| 52 | 2704 |
| 40 | 1600 |
| ⋮ | ⋮ |
| 25 | 625 |
| 543 | 19313 |

$$\frac{19313}{4} - 4607.02 = 221.23$$

| | | |
|---|---|---|
| Subtract | 49.79 | Rows |
| | 4.67 | Columns |
| | 152.29 | Treatments |
| Remainder | 14.48 | |

6. *Interaction Seasons and Rows*

| No. | Squares |
|---|---|
| 52 | 2704 |
| 31 | 2601 |
| ⋮ | ⋮ |
| 28 | 784 |
| 543 | 19069 |

$$\frac{19069}{4} - 4607.02 = 160.23$$

| | | |
|---|---|---|
| Subtract | 49.79 | Rows |
| | 61.29 | Seasons |
| Remainder | 49.15 | |

7. *Interaction Seasons and Columns*

| No. | Squares |
|---|---|
| 42 | 1764 |
| 30 | 900 |
| ⋮ | ⋮ |
| 33 | 1089 |
| 543 | 18723 |

$$\frac{18723}{4} - 4607.02 = 73.73$$

| | | |
|---|---|---|
| Subtract | 4.67 | Columns |
| | 61.29 | Seasons |
| Remainder | 7.77 | |

8. *Interaction, Seasons and Treatments*

| No. | Squares |
|---|---|
| 49 | 2401 |
| 35 | 1225 |
| ⋮ | ⋮ |
| 25 | 625 |
| 543 | 19301 |

$$\frac{19301}{4} - 4607.02 = 218.23$$

| | | |
|---|---|---|
| Subtract | 152.29 | Treatments |
| | 61.29 | Seasons |
| Remainder | 4.65 | |

9. *Interaction, Seasons and Residual*

Obtained by subtracting (1) + (2) + (3) + (4) + (5) + (6) + (7) + (8) from the total obtained by squaring all of the single plot yields and subtracting 4607.02.

| | |
|---|---|
| Total | 361.77 |
| Subtract | 344.09 |
| Remainder | 17.68 |

The sums of squares are now ready to be entered in the Analysis of Variance table.

TABLE 8.—*Complete analysis of variance for experiment to show seasonal effect.*

| Due to | Sum of Squares | Degrees Freedom | Variance | ½ $\log_e$ | $z$ |
|---|---|---|---|---|---|
| (1) Seasons | 61.29 | 3 | 20.43 | 2.6598 | 1.0687 |
| (2) Rows | 49.79 | 3 | 16.60 | 2.5560 | .9649 |
| (3) Columns | 4.67 | 3 | 1.56 | 1.3736 | |
| (4) Treatments | 152.29 | 3 | 50.76 | 3.1148 | 1.5237 |
| (5) Residual (a) | 14.48 | 6 | 2.41 | 1.5911 | |
| (6) Inter. Seas. & Rows | 49.15 | 9 | 5.46 | 2.0000 | .8588 |
| (7) " Seas. & Cols. | 7.77 | 9 | .86 | 1.0759 | |
| (8) " Seas. & Treats. | 4.65 | 9 | .52 | .8243 | |
| (9) " Seas. & Resid. | 17.68 | 18 | .98 | 1.1412 | |
| Total | 361.77 | | | | |

| $n_1 = 3$; $n_2 = 6$ | $n_1 = 9$; $n_2 = 18$ |
|---|---|
| 5% = .7798 | 5% = .4602 |
| 1% = 1.1401 | 1% = .6549 |

This analysis is of the type in which two estimates of error are obtained. The first one giving a variance of 2.41 is essentially an average over the four seasons of random errors due largely to soil heterogeneity. We must use it for comparison with the effect of seasons and treatments. In the last column

of the table $z$ values are given, and at the foot of the table the 5% and 1% points for $n_1 = 3$, and $n_2 = 6$; and $n_1 = 9$, and $n_2 = 18$. It will be noted that treatments are significantly different and that there is a quite marked effect due to seasons.

The second estimate of error comes from the interaction of seasons with the residual and represents the interaction effects not accounted for by the interaction of seasons with rows, columns, and treatments. It is therefore a random effect and furnishes a proper basis for an estimate of error with which we can compare the remaining interactions. Only one of these, that of seasons and rows is significant. This means that the yields within the rows changed from season to season in a manner which cannot be considered a purely random one.

The remaining part of the analysis can be carried out in a manner almost identical with that in the previous example. Those portions of the experiment for which average yields need be calculated and tabulated and comparisons made by means of the standard error, are now quite obvious, and we need not waste any time tabulating information which cannot yield resuts that will be of value.

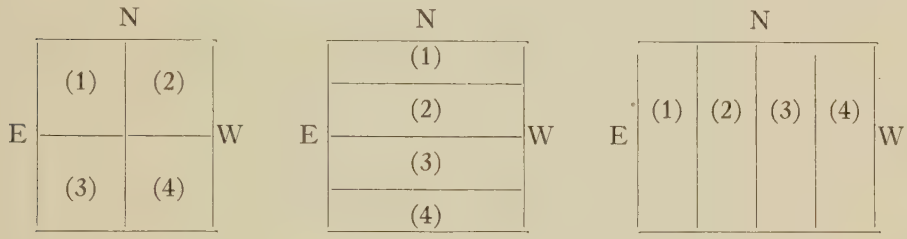
## The Shape of Field Plots

The methods of arranging field experiments described above do not consider the size and shape of the plots to be used. This is usually left to the discretion of the individual experimenter, as the actual specifications of the plots to be used will depend upon a number of factors of which he alone is the judge. However, it should be recognized that the plot specifications do matter. In general it is obvious that the larger the plots the greater the accuracy. It has been pointed out that increasing the plots beyond a certain size does not increase the accuracy of the experiment as more land means a greater range of variability. This viewpoint, however, does not take into account modern methods of arranging experiments which correct for trends in the fertility of the land. The Latin Square in particular, by correcting for rows and columns eliminates from the estimate of error the fertility gradients in both directions and with this type of experiment we would expect an increase in precision with the size of the plots to a point where the plots would be much too large for experimental work of any kind. Therefore until experiments on size plots are conducted in a manner which allows for the correction for fertility gradients we must assume from theoretical considerations that there is an increase in precision as the plots are increased in size.

The shape of field plots is also a matter which must be considered from the standpoint of modern arrangements. Evidence has been deduced to show that the rectangular plot is superior to the square one, but this again depends upon the method of obtaining the experimental error. It is therefore of interest to obtain some information on the influence of plot shape on the precision of the experiment in arrangements which are strictly in accord with modern requirements.

Mercer and Hall give the yields of wheat from one acre of wheat cut up into 1/500 acre plots. There are 25 plots in one direction and 20 plots

in the other. The data used here were taken from an area giving 20 plots in both directions, and this was divided up into 16 Latin Squares formed in different ways. Four squares were formed first by dividing the field into four quarters which were very nearly squares. Each of these squares was then considered a Latin Square in which single plots were formed by combining the 1/500 acre units in a 2 × 2 fold manner. The field was then divided into four strips running east and west, and each strip was a Latin Square in which single plots were formed from the 1/500 acre units in a 1 × 4 fold manner. Finally four strips were formed running north and south and the plots in each strip were 1 unit wide by 4 units long. The three methods of dividing the field are best illustrated in the following diagrams.




For each of these arrangements the standard error of a single plot in percent was calculated and bearing in mind that each Latin Square contained the same number of plots, the results are strictly comparable.

The results from these trials are given in table 9.

TABLE 9.—*Standard errors in percent for different shapes of plots.*

| | Plan I Plots (2x2) | | Plan II Plots (1x4) | Plan III Plots (4x1) |
|---|---|---|---|---|
| Block (1) | 6.87 | Strip (1) | 3.22 | 5.47 |
| " (2) | 5.50 | " (2) | 4.14 | 5 30 |
| " (3) | 4.18 | " (3) | 5.25 | 5.65 |
| " (4) | 8.04 | " (4) | 4.32 | 5.76 |
| Average | 6.15 | | 4.23 | 5.54 |

An inspection of Mercer and Hall's data showing the fertility gradients in the field indicates that the greater variability is from west to east. It would seem logical to assume that if lengthening and narrowing plots of a given area results in a reduction in the experimental error that the effect would be greatest if they were lengthened in the direction of the greater variability of the field. In plan II in which the plots are long from west to east and short from north to south we have the greatest reduction in the experimental error so that the results are seen to coincide with theoretical considerations.

These data while too meagre for drawing general conclusions are indicative that at least under certain conditions of soil heterogeneity, the long narrow plot is superior to the square one.

# A METHOD OF DESCRIBING WHEAT GLUMES

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[Received for publication April 2, 1931]

Since the publication of "Classification of American Wheat Varieties" by Clark, Martin, and Ball, of the U. S. Department of Agriculture, cereal breeders have given considerable attention to the possibilities of using glume characters in identifying varieties of wheat.

In this bulletin the following shape and size characters of wheat glumes are described: length of glumes, width of glumes, length of beaks, width of beaks, shape of beaks, width of shoulders, and shape of shoulders.

In some varieties an extreme is found in one or more of these characters which makes identification easy. In other cases differences between these characters in two varieties may be so small that they are practically valueless, especially because of the fact that as differences become smaller the degree of overlapping increases.

When making descriptions of wheat varieties the writer encountered considerable difficulty in selecting glumes representative of variety types for photographs. It appeared to him that there was a danger in the conscious selection of any one supposedly typical glume, of selecting one which represented a preconceived idea, rather than one which represented the mean of the variety. The following method was evolved as a solution of this difficulty, as it presented itself to the writer.

Fifty heads of each variety are selected each year from which glumes are taken for observation and measurement. Heads typical of each variety for other than glume characters are chosen. There is no selection of any particular type within what is believed to be the range of modification of the variety. This gives a random sampling of the glumes within variety limits, avoiding the inclusion of glumes from those plants which are obviously "rogues".

A diagram is drawn each year which shows the average measurements of the fifty glumes selected. Averages of the data for any period of years can be shown in the same way. The diagram shown below illustrates the average of the data collected in three seasons, and shows where the measurements are made.

A comparison of the diagrams drawn from each year's data with the diagram drawn from average data for a number of years gives the observer an opportunity of studying the influence seasonal conditions may exert quantitatively on glume characters.

As far as the writer is aware, this method has not been used previously in describing glume characters, although he has found since developing the method that a similar one has been used previously in describing wheat spikes (*1*).

* Specialist in Cereal Plant Breeding.

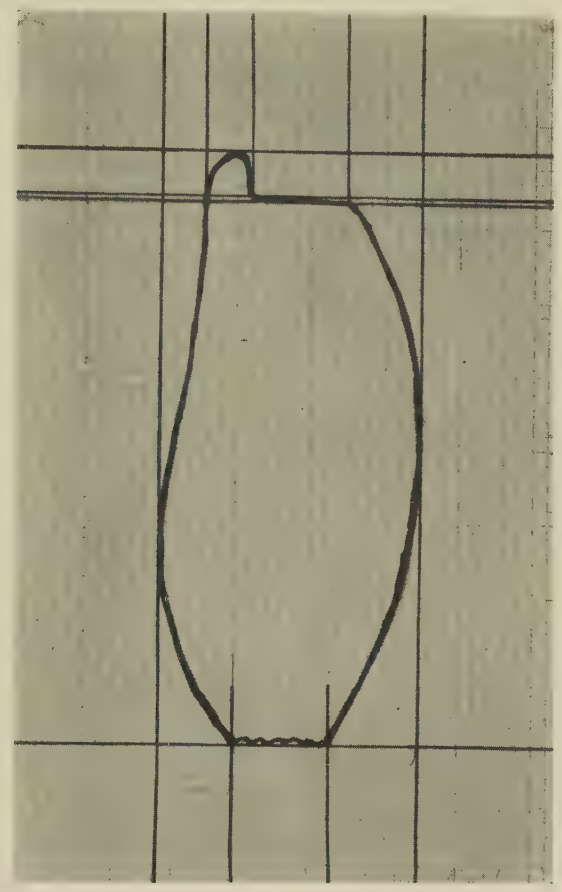

Figure 1. Secondary Glume of the Seventh Spikelet of Dawson's Golden Chaff (O.A.C. No. 61). Diagram represents three years' average. Glumes from 50 normal spikes, were measured each year. Scale—One small space represents 0.2 m.m.

The writer wishes to acknowledge the advice and assistance of Professor W. J. Squirrell, O. A. College, Guelph, Ontario; Dr. J. B. Harrington, Department of Agronomy, University of Saskatchewan, Saskatoon, and Mr. W. T. G. Wiener, Secretary, Canadian Seed Growers' Association, Ottawa, Ontario, in preparing this article.

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# RAPID METHODS OF DETERMINING THE PERCENTAGES OF FERTILITY AND STERILITY IN SEEDS OF THE GENUS BETULA *

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[Received for publication February 20, 1931]

In a preliminary study of the germination in seeds of Betula marked inconsistencies in the results obtained were found. For instance, in certain species some trees were found to produce seeds that gave a fair germination with a given treatment while other trees of the same species produced seeds that gave either a very low germination or a germination of zero with a similar treatment. Treatments that had been employed by Eckerson (*3*), Crocker (*1*), Crocker and Harrington (*2*), Harrington and Hite (*4*), Rose (*9*), Knudson (*6, 7, 8*), Ives (*5*), Shull and Davis (*10*), Tukey (*11*) and other investigators to break the rest periods in seeds of various plants were given the seeds of birch referred to, but no treatment was found that would induce germination to take place in seeds obtained from certain trees. Similar results were obtained with commercial samples of birch seed. In some cases good germination was obtained while in other cases no germination took place even after special treatments to break the rest period had been given.

With a view to ascertaining the cause of the differences in the results obtained the authors dissected and examined large numbers of seeds below a binocular microscope. Externally the seeds were found to be alike, but these examinations revealed the presence of embryos in some seeds only and the absence of them in the remainder. The sterile seeds were found to contain two small, undeveloped, shrivelled ovules and a mass of spongy tissue as shown in figure 1. Each of the fertile seeds was found to contain one fully developed ovule which filled the central portion of the winged ovary and most of which consisted of two fleshy cotyledons and a hypocotyl as shown in figure 2. A relation was found between the percentage of germination and the percentage of fertile seeds as revealed by dissection. In samples giving a fair germination, seeds with embryos were found to be abundant while in samples showing no germination seeds with embryos were absent.

With much of the commercial seed of Betula sterile and with some birch trees producing sterile seeds and others producing mainly fertile seeds the tree seedsmen and others interested in tree seeds are in need of a convenient and rapid method of determining the approximate percentage of fertility and sterility in samples of seed of this genus. To meet this need the methods outlined below were worked out.

## Methods

The method employed in the laboratory was that of examining the seeds by transmitted light below the objectives of a medium power binocular microscope. The seeds to be examined are spread thinly over a glass plate, pre-

*Seed is used here in the popular sense. The "seed" in the genus Betula is a winged nut that has developed from a two-celled ovary, each cell having one ovule. One of the two ovules is normally abortive.

†Professor of Horticulture, University of Saskatchewan, and Canadian Y.M.C.A. Agricultural Missionary in Korea, respectively.

Figure 1

Figure 2

Figure 3

Figure 4

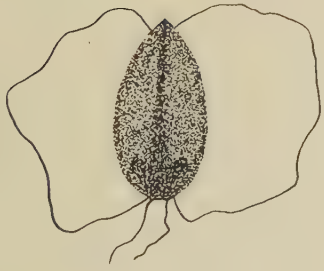

Figure 5

Figure 6

Figure 1. A sterile seed of *Betula alba* dissected. It shows the two shrunken ovules and the thickened partition between the two cells of the ovary. The partition gives the typical dark line down the middle of the sterile seed.

Figure 2. A fertile seed of *Betula alba*. The embryo with its two cotyledons and hypocotyl fills the ovary. Surrounding it is the seed coat, which is of a reddish brown color.

Figure 3. A sterile seed of *Betula alba* with a thin ovary wall as it appears over light of the proper intensity.

Figure 4. A fertile seed of *Betula alba* with a thin ovary wall as it appears over a light of the proper intensity.

Figure 5. A sterile seed of *Betula alba* with a thick ovary wall as it appears over a light of the proper intensity. In many cases the shrunken ovules are not visible. The dark line, however, is always conspicuous.

Figure 6. A fertile seed of *Betula alba* with a thick ovary wall as it appears over light of a suitable intensiity. The dark line shown in figure 5 is absent and the seed is uniformly opaque.

ferably one of ground glass, and in such a manner that the outline of each seed can be seen distinctly against the glass plate background. The plate with the seeds spread over it is then placed on the stage of the binocular microscope for examination. A good artificial light, preferably one that has passed through a "Daylight" glass, is then reflected through the glass plate by means of the mirror of the microscope. Adjustment of the mirror is necessary to give the desired illumination.

After the required adjustments have been made the operator can readily distinguish the fertile seeds from the sterile seeds. Where the ovary wall is thin the differences between sterile and fertile seeds are very conspicuous as may be seen in figures 3 and 4. Figure 3 shows a sterile seed and figure 4 shows a fertile seed. In figure 3 the outlines of the two shrivelled ovules may be seen near the base of the ovary. In figure 4, the outline of the one mature ovule that fully occupies the chamber of the ovary shows up clearly. Where the ovary wall is thick, the differences are less conspicuous but are visible as are shown in figures 5 and 6. Figure 5 shows a sterile seed with a thick ovary wall while figure 6 shows a fertile seed with an ovary wall of similar type. In this case a very dark line appears in the middle of each sterile seed and runs from the base to the apex as may be seen in figure 5. Outlines of the shrivelled ovules may be seen at the usual place. A fertile seed appears uniformly opaque and without the darker portions appearing in sterile seeds as mentioned above.

Where a low magnification is used the field of vision is large and many seeds can be examined at one time. As many as 100 seeds may be spread over the area falling within the limits of vision and this is a convenient number to use in making a fertility determination.

A method of determining the approximate percentage of fertile seeds that is simpler than the one outlined above and not requiring a microscope is that of spreading the seeds over a sheet of paper and placing this between the eye and a strong light. Any thin paper meets the requirements very well and a sixty watt or a one hundred watt bulb furnishes the necessary light. In this case no magnification is obtained but the seeds examined should exhibit the characteristics shown in figures 3 to 6. Greased paper has an advantage over ordinary paper in that the seeds remain where placed even when the sheet is held vertically or is inverted. In the field the use of greased paper is almost a necessity and if the sun is being employed as the source of light a second sheet of paper between the greased sheet and the sun may be required to reduce the intensity of the light reaching the eye .

To establish definitely that the methods used in separating fertile seeds from infertile seeds are reliable, germination tests were made. Samples of seeds were taken from individual trees and were kept separate and from each sample taken the required numbers of what were assumed to be fertile and sterile seeds respectively were drawn. These were then placed to germinate on pure quartz sand in petri dishes to which had been added either water or a solution of some agent in water. Examples of the results obtained are given in the following table.

*Percentage germination in selected seeds of Betula alba.*

| | Distilled water | Tap water | Knudson's Solution B6 (Neutral) | Knudson's solution B + 5% glucose ($pH_3$) |
|---|---|---|---|---|
| Selected fertile seeds | 90 | 100 | 100 | 100 |
| Selected sterile seeds | 0 | 0 | 0 | 0 |

The fertile seeds germinated in five to six days at a temperature of 20°C. Germination was considered as having taken place when the hypocotyl appeared through the ovary wall.

The first method outlined above has been employed in examining a great many samples of birch seed and has been found to give very satisfactory results. Samples were taken for examination from each of 237 trees of *B. alba* growing on the University campus and similar samples were obtained from various other sources. Of the 237 samples taken from trees growing on the campus only 8 were found with a fertility above 10 percent. Only three of these 8 were fertile to the extent of 20 percent. Approximately two-thirds of the 237 samples taken direct from trees were either 100 percent sterile, or fertile to the extent of less than 1 percent. The results obtained in making fertility tests on other samples by this method are as follows:

*Percentage of fertile seeds in samples of different species of Betula.*

| Species | Origin | Percent fertile |
|---|---|---|
| *B. alba* | Arnold arboretum | 49 |
| *B. alba* | Arnold arboretum | 13 |
| *B. alba* | Purdue Agricultural Exp. Station | 0 |
| *B. alba* | Commercial sample | 54 |
| *B. alba* | Forest Nursery Station, Sutherland | 1 |
| *B. alba urticifolia* | Arnold Arboretum | 1 |
| *B. dahurica* | Arnold Arboretum | 2 |
| *B. excelsa* | Arnold Arboretum | 18 |
| *B. japonica* | Arnold Arboretum | 3 |
| *B. kamschatka* | Arnold Arboretum | 1 |
| *B. lutea* | Commercial sample | 72 |
| *B. maximowiczii* | Arnold Arboretum | 31 |
| *B. papyrifera cordifolia* | Arnold Arboretum | 60 |
| *B. pendula* | Arnold Arboretum | 4 |
| *B. pendula* | Saskatoon | 0 |
| *B. populifolia kenaica* | Arnold Arboretum | 58 |
| *B. tauschii* | Arnold Arboretum | 10 |
| *B. tristis* | Arnold Arboretum | 3 |
| *B. utilis* | Arnold Arboretum | 17 |

## Summary

1. Convenient and rapid methods of determining the percentage of fertility in birch seeds are outlined.

2. The percentages of fertility in samples of birch seeds are found to differ greatly. In most cases this percentage is very low and in few cases only is it even fair.

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## BOOK REVIEW

The Place of Agriculture in American Life. Wilson Gee. (Published by Macmillan Co., New York.; pp. 208, short bibliography, index, includes 3 charts. Price $2.).

The Virginia Professor in this little volume which is included in "The World Today Bookshelf", is attempting to present a comprehensive picture of American Rural Life in a manner which will be understood by both urban and rural readers. When the professor speaks of America he is referring always to the United States of America and his material, with very minor exceptions, is drawn exclusively from United States sources.

In his opening chapter "The Contribution of the Countryside" he reiterates or summarizes much that has been already well said in the standard text books in Rural Sociology. There is a distinct contribution, however, in summarizing in popular style the main thesis ;— that today the urban influences are dominant over the rural in the national life and that there is need for a policy which will maintain "the nice balance that will allow each of these two big parts of our civilization to flourish at its best, mutually contributing in best expression the one to the other and so constituting the only safe basis for the enduring greatness of the nation".

In the section dealing with the farmer's individualism, the author repeats some of the well worn, but scarcely substantiated statements, that the farmer is much more individualistic in his thought and action than any other worker. In no type of business, he says, "can a man be so largely his own boss as in farming". He comments on the tendency toward ultra-individualism and mentions that it has been necessary in coöperative marketing associations to

bind the members through contracts and to provide severe penalties for failure to comply. One is apt to ask, has not the Trade Union found it just as necessary to regulate and discipline its members? Practically every organization has some such provision, not as a check on ultra-individualism but as a check on human nature. Conservatism, individualism, frugality, democracy, hospitality, religiosity, according to the writer, are more notable in the country than in the city, while the "strength and purity of the home" is a marked characteristic of the countryside.

In the second chapter he deals with the progress of agriculture from self-sufficiency to commercialism, noting specially the tendencies towards mechanization and regional specialization, and concludes, "The modern farmer must, if he is to survive, master the technique of his calling in terms of the machine". He must not seek to cling to a type of agriculture (presumably the self-sufficing type) that can mean only a peasant level of existence.

In his treatment of the economic condition of the farmer he has given a very concise summary of the most recent American literature on the subject.

Under the heading of "Some Rural Social Problems", he deals with the questions;—rural standards of living, rural health, and social maladjustment, contrasting statistically the rural against the urban. Under the same heading he deals with the school, the church and rural communications.

The chapters on 'The Farmer and Politics', Co-operation in Agriculture' and 'Farm Relief' are well done, but might be considerably improved if the author had included, for the purpose of comparison, the experience of countries other than the United States.

His final chapter on 'The Future of American Agriculture' is the best part of his book. In this he brings out the contrast between American and European agriculture, which he summarizes on the basis of the emphasis which is placed on the land.

> "The processes of an older civilization have operated greatly to increase population densities and these in turn have tended to cheapen the human labour element in farming. Either consciously or unconsciously the ideal of the largest self-sufficiency in national agricultural production has accentuated this tendency."
>
> "Of course, this nation of ours, until recently has been characterized by an abundance of land, and our land policies in general have been liberal to him who would settle it. The result is that the labor element has been and still is the dear factor of our agricultural production. Consequently the emphasis in America has been and fortunately still is upon the largest returns per individual worker. In brief, in the older countries, as a general rule, the emphasis is upon the land rather than upon the man; while in this country the aim has been to exalt the man as against the land."

To pack into a volume of only 208 small pages such a variety of facts and opinions on such a wide field, and still maintain the readability is a laudable achievement. Professor Gee has gone this and this stimulating volume should help the lay reader to see in true perspective the interrelation of rural and urban life.

R.W.M.

# THE NORTHERN FOWL MITE, *LIPONYSSUS SYLVIARUM*, OF POULTRY

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[Received for publication May 2, 1931]

The Northern Fowl Mite, *Liponyssus sylviarum*, has, according to Gibson (1930), been reported on two previous occasions only in Canada, once in Ontario in 1922 and again in British Columbia in 1929. It is herein recorded as being noted at Macdonald College in the early part of this year. The mites were first observed infesting White Leghorn male birds which were being kept in individual coops in a cockerel house. Specimens of the mites were collected and identified by Mr. Alex. D. Baker of Macdonald College.

In addition to the above the same species of mite has been identified as occurring on eight different species of wild birds. These mites from wild birds were collected by Mr. J. A. Rayner during the course of poultry parasite investigations which are being carried on at Macdonald College. The above material was identified by Dr. H. E. Ewing, to whom the specimens were sent by Mr. A. D. Baker. The importance of these observations from the standpoint of the distribution of the mite from one flock to another is quite obvious.

The Northern Fowl Mite (which is also termed the Feather Mite by some writers) is smaller than the common Red Mite, *Dermanyssus gallinae*, and greyish in colour. Unlike the Red Mite they remain on the bird's body throughout the day where they can often be seen on the surface of the bird's plumage, particularly if the bird is brought into a warm atmosphere.

The control of the Northern Fowl Mite is usually more difficult than that of the Red Mite. Nicotine sulphate has been recommended as used for body lice by putting a small amount on the top of the roosts prior to roosting time. This remedy, however, has not been found to prove satisfactory in all cases. An oil spray, such as a good fly spray as used around stables or on cattle, when sprayed into the plumage of the birds has given good results. If nicotine sulphate is used care must be taken that too much is not applied to the roost as detrimental effects to the stock may result.

A spray of ten per cent nicotine sulphate has been recommended as being more satisfactory than the application of the substance to the roosts (Jull, 1930). Finely divided sulphur used as a dust is also recommended for use in cold weather. Dipping of the birds during the summer is usually more satisfactory than dusting. A satisfactory dip can be made by dissolving an ounce of soap in warm water and adding to this two ounces of sulphur.

Immediate strict attention to all birds found infected by the Northern Fowl Mite is recommended since the mite multiplies quite rapidly and great damage may result by an excessive drain on the blood supply of the host.

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# LE DEUXIEME CONGRES INTERNATIONAL DE LA SCIENCE DU SOL*

Dr. Trenel et Dr. Jacob
*Berlin*
(*Traduit par F. G. Corminboeuf, Instit. Agr. d'Oka, Qué.*)

Le deuxième Congrès international de la Science du Sol s'est tenu du 20 au 31 juillet 1930, à Leningrad et à Moscou. C'est en reconnaissance de la pédologie russe et plus particulièrement dans le but de rendre hommage à la mémoire du célèbre pédologue, feu le Prof. Glinka, que le Congrès s'est tenu en Russie. Ce Congrès a réuni un grand nombre de savants et de spécialistes en science du sol, venant de la plupart des pays du monde. Plusieurs d'entre eux y ont présenté des mémoires d'une grande importance, qui furent portés à la connaissance des congressistes afin d'être étudiés et discutés en commun. Voici un court résumé des principales communications.

Kelley et Dore, Etats-Unis, ont examiné et étudié des portions argileuses de sol ainsi qu'une argile américaine très caractéristique, la Bentonite, à l'aide des rayons de Roentgen. Il résulte de leurs recherches que la matière colloïdale du sol possède une structure cristalline ; que les bases interchangeables ne se trouvent point à la surface des plus petites particules terreuses comme le prétendait l'hypothèse de l'absorption, mais qu'elles font partie intégrante des particules cristallines elles-mêmes. De semblables recherches effectuées sur des zéolithes synthétiques et naturels, comme l'analcime, montrent que les colloïdes absorbants du sol ne leur sont point identiques.

Prianishnikov, Moscou, parla de l'influence de la réaction du sol sur la croissance des plantes. Quand on applique de la chaux au sol, on est enclin à ne penser qu'à la réaction pure et simple de celui-ci. Les recherches de l'auteur montrent cependant que l'optimum pour un pH déterminé se déplace si d'autres cathions agissent synergétiquement. C'est ainsi que dans un sol de sable la moutarde disparait avec un pH de 4.5, tandis que dans une terre noire elle se développe relativement bien pour une même valeur du pH. Des recherches effectuées sur des pois en solution nutritive prouvent que l'influence nuisible des ions hydrogène est réellement diminuée en présence du KCl ou du $K_2SO_4$.

Sir J. Russell, Rothamsted, considéra dans une interessante élocution les principes et les méthodes qui gouvernent l'utilisation des sols agricoles dans l'Empire Britannique. Pour faire un choix judicieux des récoltes à produire, il faut tenir compte des liaisons qui dépendent du climat uniquement et de celles qui résultent du type de sol et du climat.

Power, Etats-Unis, parla des rôles du soufre dans la nutrition végétale. Ses recherches rendent manifeste l'influence favorable exercée par le soufre sur la croissance de la luzerne en sols alcalins. La luzerne ayant reçu du soufre, toutes choses étant égales d'ailleurs, montre sur les témoins une augmentation en chlorophylle de 12 à 18%.

Les chercheurs russes portèrent un vif intérêt aux travaux présentés par E. Mitscherlich. Pour répondre à leurs voeux, celui-ci donna une magnifique conférence sur sa méthode de travail, conférence qui fut traduite en russe par Khirsanov de Leningrad. Ce dernier rapporta que des expé-

* Der II Internationale Kongress fuer Bodenkunde in Leningrad—Moskau vom 20-31 Juli 1930.—Die Ernachrung der Pflange—Bd. 26. Heft 24., Bl. 553-558.

riences de végétation faites sur l'avoine, le coton et la pomme de terre, durant trois années, et sur des sols correspondant à diverses zônes climatériques, confirmèrent l'intégrité de l'équation de Mitscherlich. Ainsi par exemple, il résulte des recherches que, pour le coton, le facteur d'influence de l'azote s'établit à 0.122. La concordance des faits d'expérience avec les sommes obtenues par le calcul à l'aide de l'équation de Mitscherlich s'est trouvée excellente. La difficulté majeure réside dans l'application à la grande culture de la méthode des pots d'expérience utilisée pour les recherches.

Le facteur indéterminé étant sous la dépendance du type de sol, de longues recherches à ce sujet devront être entreprises, car les divers sols possèdent des coefficients indéterminés spécifiques. Ainsi, le facteur 2, établi par Mitscherlich, correspond aux sols de l'Ouest de la Prusse et il ne s'applique nullement à ceux de la Russie. Au cours de la discussion, Bondorff, du Danemark, a fait remarquer que les diminutions de récoltes dûes à l'apport de trop grandes quantités d'éléments fertilisants ont aussi été reconnues au Danemark comme obéissant à l'équation suivante:

$$Y = ax - bx^2,$$

dans laquelle Y = rendement, x = quantité d'engrais, a et b = constantes, L'équation doit exprimer le fait que le rendement est exact quand il se trouve entre deux grandeurs effectives en opposition; disons entre un effet nutritif (ax) et un effet toxique ($-bx^2$) provenant d'une trop grande quantité d'éléments nutritifs.

Aso, Japon, parla brièvement de la croissance du riz et de l'orge en sol de réactions diverses. Il établit solidement que la croissance optima du riz en solution nutritive coïncide avec un pH allant de 4 à 5 tandis que, toutes choses étant égales par ailleurs, l'orge accuse un maximum de croissance quand la réaction est à peu près neutre. Sur des sols acides, le rendement du riz a été abaissé par l'application de chaux, tandis que celui de l'orge a été, dans les mêmes conditions, augmenté.

Walter, de Leningrad, insista sur ce fait d'une importance décisive, que pour effectuer des recherches sur la dépendance qui existe entre diverses plantes et la réaction du sol, il faut employer des variétés physiologiquement bien définies. C'est ainsi qu'en opérant avec une variété d'orge à deux rangs on a obtenu un pH5 (région acide) nettement différent de celui allégué par la littérature. La possibilité d'écarts aussi considérables exige une plus grande prudence quand les plantes doivent être utilisées comme indicatrices de la valeur du pH.

O. Eckstein, de Berlin, parla des méthodes de diagnostic pour l'établissement des exigences en potasse des sols cultivés. Les méthodes d'analyse chimique fournissent des renseignements satisfaisants sur l'ensemble de la réserve en potasse d'un sol ainsi que sur la partie de celle-ci soluble dans l'eau ou les acides, mais elles ne peuvent nous renseigner sur la réserve d'un sol en potasse assimilable. Dès lors, elles n'ont que peu de valeur pour établir les exigences des sols en potasse. La détermination de la teneur des sols en potasse assimilable en se basant sur le potassium solubilisé par la plante peut être effectuée seulement par l'observation de la croissance des plantes et l'analyse des sols sur lesquels elles ont poussé. On possède maintenant des résultats pratiques à ce sujet. Les feuilles et les tiges de certaines plantes de culture ont une teneur en fer qui varie en fonction inverse de leur teneur en potasse.

La quantité de fer de ces organes augmente quand leur teneur en potasse diminue par suite d'un manque de potasse dans le sol. Le fer peut être déterminé rapidement dans les tissus vivants des plantes par de simples réactions colorimétriques. Ce procédé fournit dans la majorité des cas une exactitude suffisante. Dans l'Ouest des Etats-Unis, Hoffer a expérimenté sur le maïs. A cet effet, il a sectionné transversalement des tiges au niveau de leurs noeuds, traitant les parties fraîchement sectionnées avec du sulphocyanure de potassium. Il a obtenu des renseignements très utiles sur les exigences des sols sous le rapport de la potasse. La méthode de Hoffer a été essayée dans une série de stations de recherches, notamment à Darmstadt-Hohenheim, à la Station de recherches du Syndicat Allemand de la Potasse, et en Afrique du Sud. Ces essais devaient établir que cette méthode ne peut être appliquée telle quelle à l'étude de tous les sols. Cependant des analyses comparatives confirmèrent dans tous les cas l'existence d'un antagonisme actif entre le fer et le potassium, non seulement chez le maïs, mais aussi chez l'orge, l'avoine, la betterave à sucre.

Pfeil, de Berlin, parla de l'influence de l'état du manganèse et du fer sur le pouvoir catalytique des sols sains ou acides, tandis que Trenel, également de Berlin, présenta un rapport de son travail sur le chimisme de l'acidité interchangeable . Il se résume comme suit. L'hydrogel d'acide silicique ne réagit pas dans une solution de KCl. La suspension aqueuse a déjà une réaction acide avec le rouge de méthyle. Après un repos, le gel $SiO_2$ est fortement coloré en rouge, et la solution surnageante possède une réaction neutre. Pour ce qui concerne l'influence du KCl sur l'hydrate-gel $Al_2O_3$ elle apparait avec une alcalinité de 20° et donne lieu à la réaction réversible suivante :

$$Al\ (OH)^3 + 3\ KCl \rightleftarrows AlCl^3 + 3\ KOH.$$

Si l'on ajoute le gel $SiO_2$ la réaction alcaline disparait et l'équilibre se déplace vers la droite en faveur de $Al\ Cl_3$. Ce fait expliquerait la présence d'aluminium dans le sol avec simultanément l'acidification de l'extrait KCl. L'acidité interchangeable se comprend dès lors comme un déplacement rétrograde des précipités de l'aluminium et du fer.

Waksman, Etats-Unis, donna un vaste aperçu sur l'état des recherches en microbiologie du sol. Au cours des sessions de la 3ème Commission, une série de conférences de grande valeur furent données sur ce sujet par Gainey, Allison, Batchelor, Curie, Burk, Aso, Leonard, Wilson, Diehm, Rubentschik, Doore de Jong, Hesselink van Suchtelen et Starkey.

Marbut, Etats-Unis, parla sur les relations qui existent entre les types de sols et leurs propriétés. Willar, Espagne, traita spécialement de la classification des sols.

Les expositions organisées pour le congrès furent d'un intérêt extraordinaire. Parmi elles citons : les Expositions de l'Institut Dokutshaïev pour l'Etude du Sol, de l'Académie Lénine, de l'Institut de Botanique appliquée, qui méritent une attention plus spéciale. Dans cette dernière Institution on peut voir un portrait de Lénine très artistique. C'est une mosaïque réalisée par la réunion de grains de semences de diverses couleurs. L'Institut possède une superbe collection de 20,000 variétés de blé, un herbier très riche, une cartographie complète, ainsi qu'une bonne bibliothèque d'ouvrages de

Génétique. L'Exposition de l'Académie Timiriasev à Moscou donna principalement une excellente vue d'ensemble sur les travaux de Prianishnikov et de ses collaborateurs. Dans cet établissement, on a exposé notamment les résultats de recherches effectuées sur la potasse. Ainsi, à titre d'exemple, une série de recherches montrent que la Néphéline a une mauvaise influence comme sel potassique, tandis que le Feldspath n'en a aucune. Ailleurs des recherches avec solutions nutritives rendent manifeste l'effet des sels de potasse sur le développement des feuilles; lorsque la solution de sels nutritifs ne contient pas de potasse, l'addition de $K_2SO_4$ fournit les meilleurs résultats. Les expériences sur les exigences nutritives des plantes exposées à la lumière ou maintenues dans l'obscurité fournissent des différences intéressantes entre les modes d'action de l'acide phosphorique et de l'azote d'une part, et ceux de la potasse d'autre part.

Les congressistes étrangers apprécièrent grandement l'occasion qui leur fut donnée de visiter les établissements scientifiques russes. Ceux-ci se signalent à l'attention par un vaste plan régulier d'organisation. Il existe une différence marquée entre les institutions dévolues à la recherche pure et simple et celles destinées à l'enseignement.

Les établissements de recherches sont réunis à l'Académie Lénine, qui dirige toutes les Stations d'expérimentation du territoire de l'Union Soviétique. Disons quelques mots sur ce genre d'Institutions: à l'Institut de Botanique appliquée, sous la direction du Prof. Vavilov, les plantes de culture sont étudiées sous tous leurs aspects, puis par l'éducation on s'éfforce d'en faire bénéficier l'agriculture russe. Dans les laboratoires de chimie agricole de l'Institut Lénine de Leningrad et Dietskoïe-Selo, qui furent également visités, les principales recherches portent sur les relations existant entre le système radiculaire des plantes et l'aménagement de l'eau, l'influence de la température et de l'éclairement sur la période de croissance des plantes, etc.

Les Etablissements d'Enseignement ont leur Centrale à l'Institut du Prof. Walter, à Dietskoïe-Selo. Dans ce genre d'Institutions il se fait aussi du travail de recherche, mais seulement dans le but de former les étudiants. On s'occupe principalement des questions de nutrition minérale dont on effectue les essais au moyen de solutions. L'influence qualitative des aliments est également soumise à la recherche. Les étudiants de ces Institutions se recrutent parmi les élèves ayant terminé avec succès leurs études à l'école publique. La durée des études est de trois ans, après quoi les élèves doivent se livrer à la pratique de l'Agriculture durant une année et demi. Alors commence la culture scientifique qui nécessite un stage d'au moins un an et demi. Elle porte principalement sur des problèmes de pratique tandis que les conférences et les cours sont limités au strict minimum. Le but assumé par cet enseignement est la formation de spécialistes et non de gens devant maîtriser l'ensemble des sciences agricoles.

Les petites et les grandes excursions qui ont eu lieu pendant et après le Congrès fournirent l'occasion d'étudier les divers types de sols de la Russie sur les lieux et en place.

Le prochain Congrès de la science du sol aura lieu en 1935, et se tiendra probablement en Angleterre.

## CONGRES ANNUEL DE LA C. S. T. A.

Le Congrès annuel de la C. S. T. A. se tiendra cette année au Collège d'Agriculture de l'Ontario, à Guelph, la semaine du 22 juin. *Les membres désirant participer au congrès sont prés d'en avertir aussi tôt que possible soit le secrétaire général à Ottawa, soit la secrétaire français à Montréal.*

La journée du 22 juin sera consacrée principalement à des réunions du Conseil de Direction de la Société. Les séances régulières commenceront le mardi matin à 9 heures et se prolongeront jusqu'au vendredi après-midi.

Une excursion aux Chutes du Niagara est prévue pour le mercredi soir.

Le coût de l'enregistrement sera $3.00 pour les membres de l'Ontario, $2.00 pour les autres membres et $3.00 pour les visiteurs qui ne sont pas membres de la C.S.T.A. L'enregistrement est gratuit pour les dames.

Le prix de la pension pour la semaine entière (du lundi au samedi matin) est de $10.00. Ceci comprend la chambre et les repas à Guelph, la chambre et les repas aux chutes du Niagara, (sauf le petit déjeuner du 25 juin), et, pour les dames, un voyage en automobile à Toronto. Ceux qui ne désirent pas rester toute la semaine obtiendront les mêmes accommodations au prix de $2.00 par jour à Guelph et $3.00 pour la journée aux Chutes du Niagara.

Le logement aux Chutes du Niagara sera fourni dans l'un des grands hotels pourvu que les chambres y soient réservées au début de juin. Si vous avez l'intention d'assister au Congrès annuel, vous êtes donc priés de remplir *immédiatement* la carte jaune qui vous a été envoyée avec le programme du Congrès et de l'envoyer aujourd'hui même soit à M. H. L. Trueman, P. O. Box 625, Ottawa, Ont., soit à M. Henry E. Lefèvre, 814, Edifice de la Banque Royale, Montréal, P.Q.

En dehors du programme régulier concernant les affaires de la C.S.T.A. et des réunions des sociétés affiliées, il y aura plusieurs conférences faites par des spécialistes sur les sujets suivants:—

"Nutrition animale" par le Dr. J. B. Orr, Aberdeen, Ecosse.

"La situation économique actuelle des cultivateurs" par le Dr. O. C. Stine, Washington, D.C.

"Les efforts de la science pour augmenter les ressources alimentaires" par le Dr. D. F. Jones, New Haven, Conn.

"La nutrition des plantes" par le Dr. G. N. Hoffer, Lafayette, Ind.

"Les travaux du Conseil National des Recherches" par le Dr. H. M. Tory.

"Le développement agricole de la Russie soviétique et son influence sur le problème du blé" par le Dr. James G. Dickson, Madison, Wisc.

## CONCERNING THE C.S.T.A.

### Convention Programme

Many favourable comments have been received on the excellence of the convention programme, both in respect to its appearance and its content. The credit for setting up the programme and getting it printed should go mainly to Professor J. Buchanan of the Ontario Agricultural College, Chairman of the Publicity Committee for the convention. Professor Buchanan has had a great deal of experience at this work and when the Ontario Committee offered to relieve the General Secretary's office of the duty of seeing the programme through the press, the offer was gladly accepted.

There will be minor changes in the detailed programme to be distributed at the convention. It is probable that the meeting of the Ontario Convention Committee and the retiring Board of Directors will be held at 11 A.M. Monday Morning, June 22nd, to permit members who are travelling by rail to reach Guelph from Toronto in time for the meeting.

In the special group sessions the special lecturer was not in all cases listed on the programme with the group to which he will lecture, but each lecturer will present a technical paper to the group most interested as well as a paper to the open session of the C.S.T.A.

Dr. G. A. Hoffer of Purdue University is unable to reach Guelph in time for the Soil Session and a place has been made for his paper on "Diagnosing Soil Deficiencies" at the open session on Friday morning, June 26th, at 9 A.M.

Reservations have been coming in rapidly and it is hoped that the Guelph convention will set a record for attendance. The local committees have all arrangements thoroughly in hand.

### Grindley Memorial Portrait

Mr. E. Wyly Grier, P.R.C.A., has completed the portrait of the late General Secretary, Fred H. Grindley, and it has been accepted by the Committee. It is felt that the artist has not not only achieved a good likeness, but has caught the spirit of the man as well, an extremely difficult task in a posthumous portrait. A very characteristic pose was selected from a photograph of the 1926-27 executive and the features worked up from a comparison of several other photographs. The outdoor background with warm sunlight filtering through dark green leaves gives a vitality to the setting which is often lacking in a more formal portrait. The man himself, while sitting at ease, has in his face all the vitality that was so characteristic of him.

It is expected that all the former Presidents of the Society will be present at the unveiling on Tuesday evening, June 23rd. Dr. L. S. Klinck, President of the University of British Columbia, will officiate at the unveiling and Dean H. Barton of Macdonald College and Dr. L. P. Roy, Director of Services of the Quebec Department of Agriculture, have been asked to give an appreciation of Grindley's services.

The ceremony will take place in the Memorial Hall at the O.A.C. at 9 P.M. Daylight Saving Time.

## Index of Research Work in Animal Nutrition Throughout the Empire.

The Imperial Bureau of Animal Nutrition with headquarters at the Rowett Research Institute, Bucksburn, Aberdeen, Scotland, has just issued an "Index of Research Work in Animal Nutrition throughout the Empire". This document is based on the information supplied to the Bureau by its official correspondents in the different parts of the Empire and sets out the various institutions engaged in research work in Animal Nutrition, together with a statement on the nature of the problems being dealt with by each. The publication which will be distributed by the correspondents will serve admirably as a contact between Empire workers. The Bureau intends to compile and issue in due course, a supplementary document containing the titles of publications, references to articles, and brief summaries of articles on work done on the particular problems mentioned in the Index. R.D.S.

## Invitation to C.S.G.A. Convention

On behalf of the President and Board of Directors of the Canadian Seed Growers' Association, the Secretary-Treasurer, Mr. W. T. G. Wiener, wishes to extend to the Canadian Society of Technical Agriculturists a cordial invitation to attend the annual meeting of the C.S.G.A. to be held at the Kemptville Agricultural School, Kemptville, Ont., June 17th to 20th, 1931.

Any members of the C.S.T.A. who can plan to attend will receive a hearty welcome. The meetings will include many interesting features in the way of technical and business sessions, special lectures, trips and entertainment. A comprehensive and detailed programme of the proceedings has been prepared and, if any C.S.T.A. members planning to make the trip will advise Mr. Wiener of their intention to do so, a copy will be sent to them promptly for their guidance and information.

The C.S.T.A. appreciates this cordial invitation and desires to reciprocate by inviting all members of the C.S.G.A. to attend the convention of the Technical Agriculturists at the Ontario Agricultural College at Guelph from June 22nd to 26th. Programmes will be forwarded on request and transportation will be arranged from Kemptville to Guelph over the week-end. Many prominent lecturers will be present and an interesting and enjoyable programme has been arranged. All are welcome to attend regardless of whether they belong to the C.S.T.A. or not.

## Notes and News

V. W. Jackson (Queen's '03) formerly Professor of Biology at the Manitoba Agricultural College, Winnipeg, has been appointed exchange lecturer at New York Summer School and will be at the Guelph Convention enroute to New York.

R. P. Longley (Toronto '31) has returned to Truro, N.S., after a year's post graduate work in the Department of Economics at the University of Toronto, and will be located at the Nova Scotia Agricultural College, Truro.

V. Logan (McGill '30) has changed his address from Amherst, N.S., to 113 Melrose Ave., Ottawa, Ont.

T. O. Graham (Toronto, '28) has returned from post graduate work at the University of Minnesota and has resumed his duties at the Dominion Experimental Station, Morden, Man.

E. E. Eisenhauer (Saskatchewan '18) has changed his address from 1016—14th Ave. W., Calgary, to Box 939, L. N. Colonization Department, Lethbridge, Alta.

A. E. MacLaurin (Toronto '14) formerly Live Stock Superintendent for the Province of New Brunswick, has arrived in Ottawa to take charge of his work as General Secretary of the Canadian Council on Boys and Girls Club Work, and is located in Room 435 Confederation Building, Ottawa.

W. H. Wright (Toronto '12) was highly honoured at the recent spring show of the Ottawa Art Association when a picture painted by him was selected by Mrs. W. D. Herridge, wife of the Canadian Ambassador to United States, as a wedding present. Mrs. Herridge, formerly Miss Mildred Bennett, sister of Premier R. B. Bennett opened the show the day before her wedding and was given her choice of a large number of pictures on exhibit. The picture chosen is entitled "A Cloud Study" and is one of the best pieces of work that Mr. Wright has done. It was a pleasure to see his fine piece of restrained work chosen in preference to many of the so-called "modern" pictures on exhibit.

H. T. Gussow, Dominion Botanist, was honoured at the recent convocation at Queen's University with the degree of LL.D. On May 20th he was received as a fellow of the Royal Society of Canada. This election takes place as a result of outstanding work in research, and will be received with approval by the technical agriculturists of the Dominion.

S. J. Chagnon (Ottawa '17) has been appointed Director of the Provincial Nursery at Deschambault, Port Neuf Co., P.Q.

W. S. Chepil (Saskatchewan '30), formerly on the staff of the Field Crops Branch of the Saskatchewan Department of Agriculture, has been transferred to the staff of the Dominion Department of Agriculture at Regina, in charge of the Regina Experimental Sub-station under J. G. Taggart, Superintendent of the Swift Current Dominion Experimental Station.

W. G. Bonnor (Saskatchewan '31) has joined the district representative staff of the Field Crops Branch of the Saskatchewan Department of Agriculture, his headquarters being at Wilkie, Sask.

Murray S. Cooke (Saskatchewan '31) has been appointed to the district representative staff of the Field Crops Branch of the Saskatchewan Department of Agriculture, with headquarters at Swift Current, Sask.

## New Members

The following applications for regular membership have been received since April 1st, 1931:

Cameron, Don (Alberta, 1930, B.Sc.), Edmonton, Alta.

Charnetski, A. J. (Alberta, 1930, B.S.A.), Edmonton, Alta.

Chepesuik, M. W. (Toronto, 1930, B.S.A.), Toronto, Ont.

Davis, F. R. (Alberta, 1930, B.Sc.), Edmonton, Alta.

Fair, H. D. (Toronto, 1930, B.S.A.), Arthur, Ont.

Groves, J. W. (Toronto, 1930, B.S.A.), Toronto, Ont.

Hansuld, A. F. (Toronto, 1920, B.S.A.), Port Arthur, Ont.

Harrison, M. P. (Toronto, 1930, B.S.A.), Gagetown, N.B.

Leclerc, Marc (Laval, 1930, B.S.A.), Ste. Anne de la Pocatière, P.Q.

Marritt, W. G. (Toronto, 1917, B.S.A.), Hamilton, Ont.

MacKenzie, J. C. (British Columbia, 1930, B.S.A.), Vancouver, B.C.

Pavlychenko, T. (Saskatchewan, 1930, B.S.A.), Saskatoon, Sask.

Petty, D. F. (Toronto, 1930, B.S.A.), Guelph, Ont.

## Bulletin Review

In Macdonald College Technical Bulletin No. 8, Dr. J. E. Lattimer, Professor of Agricultural Economics, has presented an analysis of a national problem—"Barley or Bacon." His study is entitled, "Broadening the Base of Export Trade," and bears a foreword by Dean H. Barton calling attention to the lack of sound policy in correlating western grain production and eastern feeding practices. While many technical agriculturists have felt the need of the establishment of a national policy along this line, so many obstacles have been in the way that no one seem to have been able to accomplish much. No one has even been sure enough of the facts of the case to present a reasonably complete picture.

It has remained for the economist to undertake this task, and Dr. Lattimer has succeeded admirably in presenting the case. It is impossible to review the bulletin in brief as it is a review itself of the wide range of factors entering into the development and the possible correction of the present situation. Taking the stand that a decrease in barley production would probably be replaced by an increase in wheat, which is a doubtful policy at present, Dr. Lattimer summarizes the case as follows:

"The problem in the final analysis is a question of which is the most hopeful prospect—the world market for barley or that for bacon? It has been suggested that Canadian farmers cannot compete with the thrifty Dane in this line of effort. If this be true, then, is there any more hope of competing with the growers of barley of eastern Europe? The question is not one of comparison between different countries but rather is a question of the comparative advantage of selling barley as grain or as meat. This is in accordance with the well known law of comparative costs. It is a national question of whether or not we may find an outlet for barley in order that its acreage may expand or at least not be decreased. The United States is on the export market for pork products on account of the hog providing a suitable market for corn which is adaptable to the corn belt. If the growing of feed barley is attractive, as present acreage and amount on hand appears to indicate, this alternative method of marketing barley may merit more consideration.

The present condition need not continue. The remedy is fairly obvious. The remedy consists of organizing the business of supplying feed grains to the feeder at such a price that he will be induced to expand his business.

This may be more profitable to all concerned. On this account it is not a question concerned only with one section or with any class. It is a national

problem. The opportunity now presents itself of planning to provide against the present difficulty recurring and of placing feeding on a more permanently prosperous basis. This opportunity if embraced will lessen the dependence on wheat, to the end that Canada may not be financially jeopardized when wheat does not grow or sell to advantage."

## C.S.T.A. Employment Bureau

An assistant is required to handle garden vegetable and forage crop work. Candidates must be graduates of a Canadian agricultural college and have special knowledge of these subjects. Salary would be arranged commensurate with the amount of experience and previous training of applicant. Please give full history of experience and qualifications, and address reply to: Position No. 107 C.S.T.A. Employment Bureau, P.O. Box 625, Ottawa, Ont.

# C.S.T.A. Convention

## O. A. C., Guelph Ontario

## June 22nd to 26th

Monday—Phytopathologists, Agricultural Representatives and C.S.T.A. Committee Meetings.

Tuesday—Group Sessions and Open Lectures.

Wednesday—Group Sessions and Tour.

Thursday—Tour of Niagara Peninsula and visit to Vineland.

Friday—C.S.T.A. Business Sessions and O.A.C. Class Reunions.

Saturday—O.A.C. Alumni Day.